SEWAGE WORKS JOURNAL

VOLUME XX

JAN.–DEC.

1948

W. H. WISELY, *Editor*
F. W. MOHLMAN, *Advisory Editor*

Published by
Federation of Sewage Works Associations

Sewage Works

INDUSTRIAL USES OF RECLAIMED SEWAGE EFFLUENTS *

By N. T. Veatch

Black and Veatch, Consulting Engineers, Kansas City, Mo.

The desire to salvage something of value from sewage is not new; in fact, considerable accomplishment has been made along that line since the time water carriage collecting sewers came into existence nearly a century ago. The first use of sewage effluent was for irrigation, many of the early systems combining the salvage of water and the disposal of the sewage in broad irrigation. This practice is still followed in a few instances.

Values in Sewage

The utilization of sewage sludge for fertilizer has received much study and its practicability is evidenced by the practice at Milwaukee, Chicago, and elsewhere. Generally speaking, the salvage of sewage solids, though proven feasible, has resulted only in the reduction of total cost of sewage treatment rather than in actual profits to the complete process of sewage disposal. The primary reason for this is that sanitary sewage ordinarily contains about 0.03 per cent of recoverable materials other than water and therefore must be classed as unusually "low-grade ore" so far as processing is concerned.

A second reason, which applies particularly to the manufacture of fertilizer, is that in each case the source of raw material is strictly limited by the size of the community served. Mass production methods are feasible only in very large installations and, therefore, unit costs of production, so far as the plant of ordinary size is concerned, are relatively high as compared with those of commercial enterprises which may obtain raw material as needed. Where actual profits have been realized, it has been due to the value of the water, as such, rather than that of any other ingredient of the sewage.

It seems probable that the salvage of the water in sewage, for uses in which human consumption is not involved, may be more generally attractive from an economic standpoint than the salvage of solids, and therefore deserves more attention from those engaged in the water and sewage works fields than it has received in the past.

The use of sewage and sewage effluents for irrigation is well established and in arid or semi-arid areas it represents a salvage value far in excess of that possible from the solids in sewage. Due to climatological and topographical limitations, however, it is probable that this method can never have general application.

Feasibility of Industrial Usage

Relatively recent and undoubtedly successful experience with the use of sewage effluents for industrial purposes indicates that this use may represent a real economic possibility. In a

* Presented in symposium "Reclamation of Sewage Effluents" at the 20th Annual Meeting of the Federation of Sewage Works Associations, in joint session with the American Water Works Association; San Francisco, Calif.; July 23, 1947.

number of instances the costs incident to the successful use of effluent have been found to be less than those involved in the development of an equal amount of additional water, and it is pertinent to note in this connection that unless unusual amounts of soluble mineral salts are involved, the treatment required is neither difficult nor expensive. A survey of the general practice in this country brings out the facts that:

1. The use of sewage effluents for industrial purposes is limited to a relatively few instances.
2. Such use is limited to instances where an adequate supply from ordinary sources is either very expensive or actually not available.
3. The problems involved in fulfilling the requirements of the public health and of the industry simultaneously are actually not difficult.

It is probable that in the majority of cases the use of sewage effluents is a matter for future rather than immediate consideration, but it is a fact that in many instances the demand for water is increasing while the development of additional water is relatively expensive or even impractical.

Industrial requirements for water are quite varied as to quality but are commonly relatively uniform as to demands. Seasonal peaks are usually less prominent than those due to other municipal uses, particularly sprinkling. There are some exceptions, but in general the industries which can use treated sewage (*i.e.*, where human consumption is not involved) operate on a fairly even basis throughout the year. This is an important factor, particularly when several months of storage is a part of the water supply works, since if the relatively even industrial demand is met from another source, more of this storage becomes available for use during seasonal peaks of ordinary demand.

In perhaps a majority of cases the sewage flow of the city is at least as great as the demands of its industries and it follows that, so far as the latter are concerned, provision for the use of sewage effluent, when economically justified, assures an ample and cheap water supply.

Case Histories

In the preparation of this paper, letters were sent to the engineers of all state boards of health in the United States, asking for a list of places, if any, where salvage of sewage effluents was practiced. Answers were received to all letters sent out, and it is desired to acknowledge and express appreciation for this assistance. A 100 per cent reply to any questionnaire is unusual and certainly worthy of special acknowledgment.

From the information gained from the state sanitary engineers, and from direct correspondence with the cities making use of sewage effluents, it was determined that there were apparently only nine instances in this country where sewage effluents were being used, or contemplated, for industrial purposes. In only four of these cases was revenue—which could be credited to sewage disposal operations—being derived from such practice.

It is doubtful that the studies back of this paper could be considered as conclusive so far as the actual number of instances where sewage effluents are being salvaged for industrial purposes, but it does establish the fact that the number is very small.

The nine reported instances in which sewage effluents are reclaimed for use in industry are described briefly herewith.

Herington, Kan.

This east central Kansas city has a population of 3,800 and is a division point on the Rock Island railroad. The problem of water supply is particularly difficult since there are no permanent streams, and ground water is highly mineralized. The only source of satis-

factory water is impounded surface runoff and the city has developed the only really feasible reservoir site within reasonable distance.

Prior to 1934, the Rock Island railroad obtained its water supply from wells, located fairly close to the site of the proposed sewage treatment plant. Studies disclosed that it would be possible to furnish a purified effluent from the treatment plant at a price that would make the disposal of sewage self-liquidating, and at the same time result in appreciable saving to the railroad in cost of softening. The demand of the railroad was less than the available sewage flow, so a definite and satisfactory water supply would be assured if arrangements could be made for it to abandon the wells and purchase sewage effluent.

While it had no particular bearing upon the situation at Herington, the demands of the railroad represented approximately half of the available supply from the city's impounding reservoir. It would have been impossible for the city to supply the railroad from its domestic supply without going to a great deal of expense in developing additional supply. This is considered to be an important point, as in many cases the advisability of using sewage effluent hinges on the economic balance between the cost of additional supply and the purification of the effluent.

In order to make a softer water available to the railroad, as well as to create a source of revenue to the city, an agreement was made in 1933 whereby the city delivers effluent from its activated sludge plant to the softening plant of the railroad, under a sliding scale of rates which ranges from $0.05 to $0.07 per 1,000 gal. delivered.

This plan has been in continuous and successful operation since early in 1934, and an analysis of the revenues and disbursements during the past 13 years shows a balance of $1,668.43, as follows:

Total receipts (all sources)	$103,554.17
Total of disbursements for same period inclusive of operation, maintenance, interest and the retirement of $39,000 of the original bond issue of $65,000.	101,885.74
Cash on hand Jan. 1, 1947.	$ 1,668.43

The pertinent facts disclosed by this record are:

1. The industry has enjoyed and is enjoying the use of a satisfactory water supply at costs much lower than those involved in the development and use of any other available source. The recent extension of the original agreement at the request of the industry is substantial proof that the effluent is satisfactory.

2. The city water department is furnishing a service that would be impossible without a sizable additional capital outlay.

3. The sanitary sewage has been given highly satisfactory treatment for a period of 13 years at no expense to the city and there is no reason to doubt that revenues will equal costs in the future.

A further breakdown of the disbursements during the 13-year period is as follows:

Operation and maintenance	$ 32,335.74
Interest	30,550.00
Retirement of debt	39,000.00
Total for 13 years	$101,885.74
Average annual disbursement	$ 7,837.36

The average annual disbursement actually represents the cost of sewage disposal which would, ordinarily, have been met by taxes. The tax equivalent is therefore $2.06 per capita or approximately 2.5 mills per dollar of assessed valuation.

It is interesting to note that debt has been retired at the uniform rate of $3,000 annually, which is 4.6 per cent of the capital investment of $65,000 and is the rough equivalent of the annual depreciation of the sewage treatment plant.

Grand Canyon, Ariz.

Possibly the earliest installation for the reclamation of sanitary sewage for industrial use is at Grand Canyon, Ariz., where the cost of water from springs is about $2.00 per 1,000 gallons and that of water hauled in railroad tank cars is about $3.00 per 1,000 gallons.

The sanitary sewage, after treatment by the activated sludge process, is coagulated, filtered and sterilized prior to distribution to uses which include stationary boilers, locomotives, toilet flushing, and lawn irrigation.

Due to the nature of the development at Grand Canyon, which is a resort of the highest class operated jointly by the U. S. Government and the Santa Fe railroad, the treatment of the sewage is unusually complete. Conventional methods for the purification of both sewage and water are employed and a characteristic analysis of the reclaimed product is as follows: 5-day B.O.D.—1.5 p.p.m.; suspended solids—trace; *B. coli*—less than 1 per cent of 10 ml. test portions showing presence of *coli-aerogenes* group. In other words, outside of its questionable past, the reclaimed effluent is good drinking water. Regardless of its safe quality, the effluent is distributed in a separate system of pipes of which all visible portions are painted a bright red. Warning signs are prominently placed at places of possible use and connections are made under rigid regulations.

The cost of the reclaimed effluent is reported by John O. Cook (*Official Bulletin,* Arizona Sewage and Water Works Association, March, 1946), to be $0.30 per 1,000 gal. which, while quite high from the standpoint of sewage disposal, is from 10 to 13 per cent of the cost of water from any other available source.

The amount of effluent is relatively small (approximately 150,000 g.p.d.) but due to unusual conditions its use is relatively important economically.

Corpus Christi, Texas

For a period of about two years during the late war, the effluent from a trickling filter at Corpus Christi was used by an oil refinery for cooling and condensing. It was found that the control of slime by chlorination was a necessary treatment step but that the effluent so treated was satisfactory. The effluent was used until the plant was shut down and dismantled.

In describing the operations at Corpus Christi, S. L. Allison, Superintendent of the Sewer Department, made the following pertinent statement: "Circumstances created the market for sewage effluent before the effluent was available. This market was caused by the adjacent oil fields furnishing a high grade gasoline crude oil, tide water shipping, and an overloaded city water system." Unusual conditions existed, therefore, which made the salvage of sewage effluent necessary and desirable.

The revenue from the sale of effluent ranged from $486 to $625 per month, and was expected to go to more than $100 per day with enlargements made to the refinery. The plant is shut down at present.

Baltimore, Md.

So far as quantity of effluent is concerned, it is probable that the experience at Baltimore should head the list. In this case, a substantial portion of the effluent is sold for cooling, quenching and possibly other uses in steel mills. (The Baltimore experience is covered in detail in another paper in this issue.—Ed.)

Big Spring, Texas

Approximately one-half of the effluent from the sewage treatment plant which serves the city of Big Spring, Texas, is being purchased by an oil refinery for use in cooling and as boiler feed. The plant is of the contact aeration type and the effluent is stored in an earthen reservoir from which the

portion used by the industry is pumped as needed, by its own equipment.

The usage amounts to approximately 18,000,000 gal. per month and produces a revenue of about $800 per month, or roughly 90 per cent of the costs to the city of operating and maintaining the sewage works.

The effluent, after chlorination for slime control, has been satisfactory and its use represents an estimated saving to the industry of $0.05 per 1,000 gal. or about $10,800 per year, as compared with the costs involved in the development and use of ground water, which is the only other available source. The ground water is limited in quantity and unattractive from the standpoint of mineral content.

Enid, Okla.

Due to the inadequacy of the original ground water source, a large portion of the water used by an oil refinery at Enid, Okla., is taken from an intermittent stream, the dry weather flow of which is the effluent of the trickling filter plant serving the city of Enid. The effluent is clarified in a tank of the "Accelator" type at the refinery, and is used for cooling and as boiler make-up.

The current program of sewage treatment for the city involves the use of a site below the refinery, and it is interesting to note that the industry plans to construct a pumping station at the plant outlet in order to get the effluent directly and escape the periods of high turbidity in the stream.

Here is a case where it would seem that the city should be getting some revenue for providing a water supply to the oil company.

Duncan, Okla.

A refinery at Duncan, Okla., uses water from an intermittent stream, under conditions similar to those at Enid, and gives it similar treatment.

Goldfield, Nev.

Due to chronic shortage of water, settled sewage from the municipal sewage treatment plant is used in metallurgical processes at a local mill which employs the cyanide process.

Providence, R. I.

Sewage treatment plant effluent is used for cooling purposes at the nearby municipal incinerator.

Cheyenne, Wyo.

The production of an industrial water supply from the effluent of a proposed sewage treatment plant of the trickling filter type has been studied and has been given favorable consideration by the Cheyenne, Wyo., Board of Public Utilities, which operates both the water works and the sanitary sewer system.

It is estimated that the current demand of industries for purposes which do not involve human consumption is approximately 3.0 m.g.d., and that the plant effluent may be softened, filtered and delivered to the customers' premises at a total cost of approximately $0.045 per 1,000 gallons. This cost is lower than that of furnishing water from the municipal supply and a great deal lower than that of developing and furnishing the same amount of water from any other available source.

Discussion

The experience at the nine cities mentioned above is not presented as a complete outline of the use of sewage effluents for industrial purposes, but rather as evidence that such use is actually feasible and can be economical.

It will be recognized that three conditions must exist simultaneously in order to make the plan worthy of consideration:

1. There must be a local industry in need of water for purposes that do not involve human consumption.

2. There must be a sewage treatment plant large enough to furnish the amount of effluent required.

3. The costs of processing and furnishing effluent must be less than those involved in the use of another source of supply.

With the foregoing in mind, it is interesting to know that the reclamation of sewage is a step that can be taken when the necessity arises and that a great deal of the aversion to the use of sewage in any form is actually unwarranted. As a matter of fact, the effluent from a modern sewage works of the complete treatment type is a better supply than many raw water supplies that are being purified for domestic use. Surely, there can be no good reason for not salvaging sewage effluents for industrial purposes when the practice is economically justified.

There may even be cases where the salvaging of sewage effluents for re-use as domestic supplies would be justified, but such a practice would undoubtedly have to be camouflaged in some way to overcome public resistance. A survey made by the Kansas State Board of Health a number of years ago indicated that during the summer months the total river water used by cities along the Verdigris River in Kansas was 17 times the total flow of the stream at the state line, where the stream left the state. Undoubtedly, sewage effluents were being salvaged for domestic use in this instance.

As to the feasibility of using sewage effluents for industrial purposes, from the standpoint of the industries themselves, there are examples all over the country where such water supplies are so used. A good example is the situation along the North and South Branches of the Chicago River, the flow of which is made up largely of treated sewage. Here the water from these streams is in rather general use by industries for cooling and condensing. The natural inference is that this source is used in preference to the public supply for reasons of economy. There are many other similar examples.

Many cities can, by the salvage of sewage effluents for industrial purposes, extend materially their ability to offer adequate water supplies to prospective industries. The potential water supply available from sewage effluents is enormous, and should not be overlooked where conditions and economics warrant. Sewage treatment plant effluents should be considered as a natural resource, and where at all possible, the cities supplying such should arrange to sell them as a definite commodity. As a product of the sewage system, the revenue from sale of treated effluents would be credited against the cost of the service.

Census of Sewage Effluent Utilization

Table I lists the places in the United States at which sewage effluents are being utilized, the industries using them, and the uses to which they are put. The information has been taken from "Sewage Irrigation as Practiced in the Western States" by Wells A. Hutchens, contained in Technical Bulletin No. 675, U. S. Department of Agriculture (March, 1939), and from data supplied by or through the various state sanitary engineers. The information is not represented as being entirely complete or accurate, but does represent the best census data available.

The table shows that sewage effluents are being utilized at 135 locations in 18 states. The purposes for which the salvaged water is used include: agriculture (124 places), oil refining (4), steel production (2), railroads (2), municipal incinerator (1), mining (1) and amusement (1).

Acknowledgment

Grateful acknowledgment is made to the city engineers, sewage works superintendents, state sanitary engineers and others who furnished much of the information set forth in this paper.

TABLE I.—Census of Sewage Effluent Reclamation in the United States

State and City	Industry Served	Use	Remarks
ARIZONA			
Casa Grande	Agriculture	Irrigation	Used directly.
Nogales	Agriculture	Irrigation	Used directly.
Phoenix	Agriculture	Irrigation	Diverted from stream.
Tucson	Agriculture	Irrigation	Used directly.
CALIFORNIA			
Bakersfield	Agriculture	Irrigation	Used directly.
Banning	Agriculture	Irrigation	Used directly.
Brea	Agriculture	Irrigation	Diverted from stream.
Chino	Agriculture	Irrigation	Used directly.
Cloverdale	Agriculture	Irrigation	Used directly.
Colfax	Agriculture	Irrigation	Used directly.
Colton	Agriculture	Irrigation	Used directly.
Corcoran	Agriculture	Irrigation	Used directly.
Dixon	Agriculture	Irrigation	Used directly.
Elsinore	Agriculture	Irrigation	Used directly.
Exeter	Agriculture	Irrigation	Used directly.
Fowler	Agriculture	Irrigation	Used directly.
Fresno	Agriculture	Irrigation	Used directly.
Hanford	Agriculture	Irrigation	Used directly.
Hemet	Agriculture	Irrigation	Used directly.
Indio	Agriculture	Irrigation	Used directly.
Kingsburg	Agriculture	Irrigation	Used directly.
Lemoore	Agriculture	Irrigation	Used directly.
Livermore	Agriculture	Irrigation	Used directly.
Lodi	Agriculture	Irrigation	Used directly.
Madera	Agriculture	Irrigation	Used directly.
Manteca	Agriculture	Irrigation	Used directly.
Marysville	Agriculture	Irrigation	Used directly.
Merced	Agriculture	Irrigation	Used directly.
Modesto	Agriculture	Irrigation	Used directly.
Ontario	Agriculture	Irrigation	Used directly.
Orland	Agriculture	Irrigation	Used directly.
Pasadena	Agriculture	Irrigation	Diverted from stream.
Pomona	Agriculture	Irrigation	Used directly.
Ripon	Agriculture	Irrigation	Used directly.
Riverside	Agriculture	Irrigation	Used directly.
San Bernardino	Agriculture	Irrigation	Diverted from stream.
San Louis Obispo	Agriculture	Irrigation	Used directly.
Santa Maria	Agriculture	Irrigation	Used directly.
Santa Paula	Agriculture	Irrigation	Used directly.
Santa Rosa	Agriculture	Irrigation	Diverted from stream.
Selma	Agriculture	Irrigation	Used directly.
Sonoma	Agriculture	Irrigation	Used directly.
St. Helena	Agriculture	Irrigation	Used directly.
Susanville	Agriculture	Irrigation	Used directly.
Tracy	Agriculture	Irrigation	Diverted from stream.
Tulare	Agriculture	Irrigation	Used directly.
Turlock	Agriculture	Irrigation	Used directly.
Ukiah	Agriculture	Irrigation	Used directly.
Vacaville	Agriculture	Irrigation	Used directly.
Visalia	Agriculture	Irrigation	Used directly.
Wasco	Agriculture	Irrigation	Creamery wastes, used directly.
Whittier	Agriculture	Irrigation	Used directly.
Woodland	Agriculture	Irrigation	Used directly.
Yreka	Agriculture	Irrigation	Used directly.

TABLE I (cont.).—Census of Sewage Effluent Reclamation in the United States

State and City	Industry Served	Use	Remarks
COLORADO			
Burlington	Agriculture	Irrigation	Diverted from stream.
Colorado Springs	Agriculture	Irrigation	Diverted from stream.
Denver	Agriculture	Irrigation	Diverted from stream.
Greeley	Agriculture	Irrigation	Diverted from stream.
Holyoke	Agriculture	Irrigation	Diverted from stream.
IDAHO			
Glenns Ferry	Agriculture	Irrigation	Used directly.
Meridian	Agriculture	Irrigation	Used directly.
KANSAS			
Herington	Railroads	Boiler water	Used directly with softening.
Liberal	Agriculture	Irrigation	Used directly.
Scott City	Agriculture	Irrigation	Used directly.
MARYLAND			
Baltimore	Steel mills	Cooling and quenching	Treated and used directly.
MONTANA			
Anaconda	Agriculture	Irrigation	Used directly.
Helena	Agriculture	Irrigation	Used directly.
White Sulphur Springs	Agriculture	Irrigation	Used directly.
NEBRASKA			
Grand Island	Amusement	Skating	Used directly by ponding.
Hastings	Agriculture	Irrigation	Diverted from stream.
Imperial	Agriculture	Irrigation	Used directly.
Kimball	Agriculture	Irrigation	Used directly.
NEVADA			
Goldfield	Mining	Processing ore	Used directly.
Reno	Agriculture	Irrigation	Diverted from stream.
NEW JERSEY			
Vineland	Agriculture	Irrigation	Used directly.
NEW MEXICO			
Clovis	Agriculture	Irrigation	Used directly.
Hobbs	Agriculture	Irrigation	Used directly.
Lordsburg	Agriculture	Irrigation	Used directly.
Portales	Agriculture	Irrigation	Used directly.
Raton	Agriculture	Irrigation	Diverted from stream.
Santa Fe	Agriculture	Irrigation	Used directly.
OKLAHOMA			
Duncan	Oil	Cooling	Diverted from stream.
Enid	Oil	Cooling	Diverted from stream.
OREGON			
Ashland	Agriculture	Irrigation	Diverted from stream.
Athena	Agriculture	Irrigation	Used directly (creamery wastes).
Burns	Agriculture	Irrigation	Used directly.
Hillsboro	Agriculture	Irrigation	Used directly (cannery wastes).
Medford	Agriculture	Irrigation	Diverted from stream.
Milton	Agriculture	Irrigation	Used directly (creamery wastes).
Milton	Agriculture	Irrigation	Used directly (cannery wastes).
RHODE ISLAND			
Providence	City incinerator	Cooling	Used directly.
TEXAS			
Abilene	Agriculture	Irrigation	Used directly.
Amarillo	Agriculture	Irrigation	Used directly.
Baird	Agriculture	Irrigation	Used directly.
Big Springs	Oil	Cooling	Used directly.
Brady	Agriculture	Irrigation	Used directly.

TABLE I (cont.).—Census of Sewage Effluent Reclamation in the United States

State and City	Industry Served	Use	Remarks
TEXAS (*cont.*)			
Breckenridge	Agriculture	Irrigation	Used directly.
Brownfield	Agriculture	Irrigation	Used directly.
Canyon	Agriculture	Irrigation	Used directly.
Carlsbad (State Sanitarium)	Agriculture	Irrigation	Used directly.
Childress	Agriculture	Irrigation	Used directly.
Coleman	Agriculture	Irrigation	Used directly.
Corpus Christi	Oil	Cooling	Used directly.
Dublin	Agriculture	Irrigation	Used directly.
Falfurrias	Agriculture	Irrigation	Used directly.
Georgetown	Agriculture	Irrigation	Used directly.
Karnes City	Agriculture	Irrigation	Used directly.
Kerrville	Agriculture	Irrigation	Used directly.
Kingsville	Agriculture	Irrigation	Used directly.
Lubbock	Agriculture	Irrigation	Used directly.
Midland	Agriculture	Irrigation	Used directly.
Mission	Agriculture	Irrigation	Used directly.
Munday	Agriculture	Irrigation	Used directly.
Plainview	Agriculture	Irrigation	Used directly.
Robstown	Agriculture	Irrigation	Used directly.
Roscoe	Agriculture	Irrigation	Used directly.
Rotan	Agriculture	Irrigation	Diverted from stream.
San Angelo	Agriculture	Irrigation	Used directly.
San Antonio	Agriculture	Irrigation	Used directly.
San Marcos	Agriculture	Irrigation	Used directly.
Snyder	Agriculture	Irrigation	Used directly.
Stamford	Agriculture	Irrigation	Used directly.
Stephenville	Agriculture	Irrigation	Used directly.
Sweetwater	Agriculture	Irrigation	Used directly.
Tahoka	Agriculture	Irrigation	Used directly.
Uvalde	Agriculture	Irrigation	Used directly.
UTAH			
Bringham	Agriculture	Irrigation	Used directly.
Ogden	Agriculture	Irrigation	Diverted from stream.
Richfield	Agriculture	Irrigation	Used directly.
Salt Lake City	Agriculture	Irrigation	Used directly.
Salt Lake City (Geneva Steel Co.)	Steel	Cooling	Diverted from pond.
St. George	Agriculture	Irrigation	Used directly.
WASHINGTON			
Walla Walla	Agriculture	Irrigation	Used directly.
WYOMING			
Cheyenne	Agriculture	Irrigation	Used directly.
Cheyenne	Railroad	Boiler water	Proposed.

INDUSTRIAL USES OF RECLAIMED SEWAGE EFFLUENTS—A DISCUSSION

BY EARNEST BOYCE

Professor of Municipal and Sanitary Engineering, University of Michigan, Ann Arbor, Mich.

This paper presents the possibility of direct re-use of sewage effluents for certain industrial purposes where water quality standards are established by the nature of the industrial use rather than by potability requirements.

By reference to the multiple re-use for municipal water supply of the mini-

mum summer flow of the Verdigris River in Kansas, attention has been directed to the increasing pollutional load that is being carried by the many rivers that must serve a series of cities, first as sources of water supply and then as receiving streams for the disposal of sewage and industrial wastes. It is indeed proper that there be a frank recognition of the quality deterioration of many surface water supplies due to the presence of untreated or untreatable sewage and industrial waste.

There are definite limitations to the capacity of lakes and rivers to assimilate biologically and render inert the organic content of domestic sewage. Modern sewage treatment plants provide efficient biological workshops to relieve conditions of organic overload. Unfortunately, however, sewage wastes are not all organic, and consequently they are not all amenable to biological stabilization. Some wastes approach both chemical and biological stability and, except for dilution effect, they remain essentially unchanged in the receiving stream. The natural self-purification processes that normally operate to further the destruction of organic residues in a treatment plant effluent are largely ineffective.

So long as the concentration of these relatively inert sewage wastes is below the tolerance level of the quality standards that govern the re-use of the water, there is no problem. However, increases in concentration above the level require either greater dilution, a reduction in the amount of inert waste discharged, or a loss in the re-use value of the receiving body of water.

Certain industrial process waters do contain inert wastes that are objectionable from the standpoint of the quality standards of potable water. Especial reference is made to those containing mineral salts or odor and taste producing substances in concentrations well above reasonable tolerance levels. It is suggested that, if these wastes were to be separated and processed for consumptive re-use by industry, much greater progress could be made in maintaining quality standards in the public water supplies that must be obtained from rivers draining areas of industrial production.

This suggestion is not new but the problems incident to the disposal of biologically untreatable industrial wastes are serious and warrant this re-emphasis.

An excellent example of the difficulties created by an untreatable industrial waste may be found in the records of water supplies obtained from the Verdigris River, prior to the development of a satisfactory method for disposing of oil field brines.

During periods of near zero flow and consequent maximum re-use of the river, the retention time in channel storage was sufficient to effect a very complete biological stabilization of organic sewage. Little dilution was available, however, for the mineralized water from oil field drainage.

Present oil production practice provides for the separation of these brines and for their subsequent disposal through specially prepared wells leading to permeable water formations underlying those producing oil—a practice that not only removes these untreatable brines from the river but also provides the production industry with water required in the repressuring operations essential to maximum oil recovery. Thus, through the separation and consumptive use of an untreatable industrial waste, it has been possible to preserve the usability of this river as a source of public water supply.

An earlier application of the consumptive use method of disposing of untreatable industrial wastes occurred in the Ohio River valley where the state sanitary engineers by cooperative interstate action secured a reduction in the amount of phenolic wastes reaching the river by requiring

that these wastes be used for quenching coke.

The re-use of sewage effluents not only offers a possible means of increasing the quantity of usable water that can be made available to industry, but also, through separation and processing for consumptive re-use, it offers industry a possible solution for certain difficult waste disposal problems.

INDUSTRIAL USES OF RECLAIMED SEWAGE EFFLUENTS—A DISCUSSION

By R. F. Goudey

Sanitary Engineer, Los Angeles, Calif.

Mr. Veatch has presented a conservative viewpoint of this subject but is willing to recognize that such use is justifiable where economic considerations prove that such waters are cheaper than can be obtained elsewhere. It is curious to note just when so-called reclamation takes place. When sewage is placed in a lake and the same city takes water from the same lake, is not such a practice "reclamation"? If a city discharges sewage into a stream and another city takes out water below, is not this again "reclamation"?

Mr. Veatch cites a survey by the Kansas State Department of Public Health of the Verdigris River a number of years ago when the total flow of water diverted for use from the river was 17 times the flow of the river below the last user. Some fifteen years ago the only water during a dry period which flowed down the Ohio River was that which was necessary to operate the locks. The total flow of the river was used many times over for domestic and industrial use. These illustrations could be multiplied many times and they demonstrate that "reclamation" is far more commonly practiced than is ordinarily recognized.

Industries are not hesitant about reclaiming sewage effluents for developing inferior water supplies for fire protection, cooling water and process waters. This type of reclamation is the rule rather than the exception.

When direct reclamation is practiced, prejudice immediately arises even though the quality of water excels polluted waters in which the identity of the polluting material has not been altered. It is only when the scarcity of water, the cost of developing alternate supplies, and the superior mineral quality of the reclaimed effluent over other supplies are significant, that consideration is given to sewage reclamation. It would seem that other factors such as conservation, common sense, and a fairer consideration of values should be placed ahead of the usual prejudices.

To date there has been little or no attempt to compare costs of industrial water derived from sewage effluents on what might be termed a fair and business-like basis. In the case of Herington, Kan., cited by Mr. Veatch, industry bears the entire cost of sewage treatment for the community. Even if it is intended to give the community free service the cost sheet should show a credit for what the sewage treatment cost to the city should be. At the Grand Canyon installation the cost quoted by Mr. Veatch includes both the cost of sewage treatment, which would have to be carried anyway, together with the cost of that additional treatment required for reclamation. At Big Springs, Texas, the industry pays 90 per cent of the cost of sewage disposal for the community in return for one-half of the water.

It would appear logical for each community to assume what the full cost of satisfactory sewage disposal

would be if there were no reclamation, and that each industry bear not only that portion of the additional treatment needed for reclamation but also pay a charge representing water-rights. Industry should pay for all capital and operations costs representing the service received. The cost of water on the above basis represents that of securing a raw water supply, and if determined on such a basis could be compared with costs elsewhere.

The costs of transporting reclaimed water and distributing it should be kept separate, because such items will vary widely for each installation. Until such an analysis is made of "costs in sewage reclamation" the true economics of the practice will remain obscure.

INDUSTRIAL WATER SUPPLY FROM PROCESSED SEWAGE TREATMENT PLANT EFFLUENT AT BALTIMORE, MD.*

By Abel Wolman

Consulting Engineer, Baltimore, Md.

The Bethlehem Steel Company of Sparrows Point, Md., is a subsidiary of the Bethlehem Steel Company, which operates plants in several localities on the Atlantic Seaboard. It has been engaged in the manufacture of steel and its products, and in the construction of ships, for well over half a century, in Baltimore County not far beyond the boundary line of the city of Baltimore.

The Sparrows Point plant manufactures rod and wire, tin plate, rails, pig iron, nails, pipe, ships and miscellaneous steel products. It employs approximately 25,000 and will probably reach a figure of 30,000 people in the course of the next few years.

For its various industrial and domestic purposes the company uses over 185 m.g. of water per day. Of this amount, some 35 to 50 m.g.d. are of fresh water origin essential for various industrial purposes, for boiler feed water and for potable supply in the town of Sparrows Point. Large amounts of sea water are used for cooling and condenser purposes.

Underground sources for almost half a century have adequately supplied the domestic and industrial fresh water needs of the company. With plant expansion, however, and with increase in the use of the same underground reservoirs by the entire industrial area of Baltimore City, the demands upon these underground resources have grown so large and so continuous that dangerous depletions have occurred.

The static levels of water have fallen in virtually all of the wells in use and at practically all of the water bearing strata. Pumping levels have increased and the water has become increasingly contaminated by salt in varying degrees at different water bearing levels. The water bearing strata now in use extend to depths of 650 to 700 ft. below the ground level. At this depth the underlying beds of granite are encountered. In earlier underground water development, various horizons were tapped and are still used. These include depths of 150, 200, 300, 400 and 500 ft., respectively.

Owing to these circumstances the company has been confronted with the necessity of finding new sources of water supply or the expansion of existing well systems. A search was therefore made in 1941 by the writer for new sources of water supply with a minimum safe yield of approximately 50 m.g.d. Although the company at that time had not yet reached this fresh water demand, it was considered wise to develop a supply which could ultimately be exploited economically to such an amount.

Quality of Water Required

The quality of water desirable for the various industrial purposes was not easily definable, since the exact specifications of water quality for these uses were not known in detail. No unanimity of agreement existed ap-

* Presented in symposium "Reclamation of Sewage Effluents" at 20th Annual Meeting of the Federation of Sewage Works Associations, in joint session with the American Water Works Association; San Francisco, Calif.; July 23, 1947.

parently in the steel trade on the characteristics of water harmful or harmless in the individual industrial process.

These waters for the most part are used for cooling of blast furnaces and open hearths, of rolls in all the rolling mills, of gas washers, of wire machines and for the quenching and granulating of blast furnace slag and for cleaning of gases. For this reason a number of plant scale experiments were carried out in the various processes and over extended periods, in order to shed some light upon the desirable or objectionable characteristics.

These local studies, and field observations made elsewhere throughout the country, indicated that the following characteristics determine a desirable quality of water for steel manufacture. They are:

1. Temperature preferably below 75° F.
2. Chlorides preferably below 175 p.p.m.
3. pH between 6.8 and 7.0.
4. Hardness below 50 p.p.m.
5. Suspended matter below 25 p.p.m.
6. Organic content as low as possible.
7. Corrosion potential at the lowest possible level.

Possible Sources

A thorough canvass was made of the following possible future sources of water supply. The conclusions regarding each are briefly noted below.

1. *Underground Sources, Local and Distant:* These were ruled out because of possible interference with existing supplies, excessive costs and because additional yields appeared to be improbable upon further study of the available underground reservoir capacity.

2. *Baltimore City Potable Water Supply:* This was found to be inadequate in quantity and far too expensive in cost. In addition, the city was already confronted with the necessity of developing new sources of supply for its own use. Since the fresh water requirements of the company represented almost a third of the entire water consumption of the city of Baltimore, it was deemed impracticable to obtain water permanently from this source, except ultimately for potable purposes.

3. *Baltimore City Raw Water:* Studies were made on obtaining water before treatment in Baltimore City. This was ruled out on approximately the same bases as already listed immediately above.

4. *Treated Effluent of the Back River Sewage Treatment Works of Baltimore City:* This plant offered in 1941 a continuing yield of between 90 and 100 m.g.d. It was selected after careful review as the most satisfactory source of supply, sufficiently economical to be processed and delivered for industrial purposes. The features of this particular program will be given later.

5. Various other sources were explored and all were discarded as inadequate in safe yield or excessive in cost. Among these sources were the use of other surface waters in the vicinity of Sparrows Point; the treatment of the local wells for demineralization; mixing various sources to produce a controllable quality of delivered water; the use of evaporators for either underground or surface local sources, or both; and the development of more distant sources such as the Patapsco River, Gwynns Falls or the Little Gunpowder River.

Use of Processed Sewage Treatment Plant Effluent

The decision to develop a water supply with the treated effluent of the Back River Sewage Treatment Works of Baltimore City as the source rested upon the following major considerations:

1. Continuous undisturbed and probably permanent flow of not less than 85 m.g.d. For intervals of only a few hours a day this flow drops to 45 m.g.d. and rises to a maximum of approximately 165 m.g.d.

2. It is a liquid which now serves no useful purposes and produces no revenue.

3. It is within economical distance of transmission to the company plant.

4. It reflects reasonably well the desirable characteristics of water supply quality, after processing, which are necessary for company use.

5. It can be purchased at a reasonable cost which, together with the capital and operating cost to the company, will result in a reasonable total cost for industrial water supply.

Baltimore City operates two sewage treatment plants at Back River, both of conventional design. The trickling filter installation, comprising detritus tanks, primary settling, trickling filters and secondary settling, can handle well over 125 m.g.d. The activated sludge plant, of a design capacity of 20 m.g.d., normally handles not much over 15 m.g.d. The average flow in 1946 was approximately 113 m.g.d. The anticipated flow in 1960 is 120 m.g.d.

The raw sewage is a relatively strong typical municipal sewage of mixed domestic and industrial wastes, running about 250 p.p.m. of suspended matter and of B.O.D.

The Bethlehem Steel Company therefore developed an agreement, at the writer's recommendation, with the Mayor and City Council of Baltimore, which was ratified by both parties on June 20, 1941. At that time, the city of Baltimore permitted the company to take at the sewage treatment works, a maximum of 50 m.g.d. of the treated effluent from either the activated sludge or the trickling filter plant, or both.

The company uses the activated sludge plant effluent without additional processing, but with continuous chlorination at a dosage of approximately 5 p.p.m. This effluent has produced between 10 and 15 m.g.d.

The effluent of the trickling filter plant has been further processed, however, by chemical precipitation, on the grounds of the Back River Works. The treatment determined upon was the result of a long series of field and laboratory experiments with virtually all of the available coagulating chemicals.

The treatment practiced has been consistently with alum at a dose of 4 to 5 grains per gallon. An effluent is generally produced with a turbidity between 5 and 10 p.p.m. The chemicals are flash-mixed with the trickling filter plant effluent, followed by 42 min. of flocculation and 1.5 hours of settling at rated capacity.

Two settling units with continuous removal of sludge and operating in parallel were installed in 1942. Each has a capacity of 15 m.g.d., with the design permitting a flow of 20 m.g.d. through each if desired. Screening devices are provided at the outlets of each. The overflow rate is 1,140 gal. per sq. ft. per day.

Alum feed equipment was installed in duplicate, with each unit of sufficient capacity to take care of requirements at maximum flow. Provisions were made for lime feeding equipment, although experiments to date have not indicated continuous use of this chemical.

When the activated sludge effluent is inferior in quality for any reason, it is sometimes passed through the chemical processing plant for joint treatment with the trickling filter plant effluent.

All of the liquid is intermittently chlorinated at Back River to prevent slime accumulation in the transmission line to Sparrows Point. The chlorinating equipment is in duplicate with each machine capable of dosing the

full flow of 50 m.g.d., using a maximum of 10 p.p.m.

The chlorine piping is so arranged as to permit prechlorination, postchlorination, or both, of sewage leaving the chemical processing plant. Prechlorination has not proven itself to be particularly helpful, even during the summer months.

The effluent after processing at Back River is delivered to the steel company plant through approximately 24,300 ft. of 60-in. reinforced concrete transmission pipe, to the north of Humphreys Creek. This cove is dammed off and a surface storage reservoir was created with approximately 70 m.g. storage. The bulk of the flow (up to some 48 m.g.d.) from Back River to Humphreys Creek is by gravity. A booster pump will be installed at Back River or on the line for increased demands at a later date.

The water from the Humphreys Creek reservoir flows into a suction well of a high head pumping station, from which it is pumped into a new industrial water supply distribution system throughout the plant. The high head pumps operate at a head of 140 ft., with an installed capacity of 55,000 g.p.m. About 30,000 ft. of cast iron distribution mains, varying in size from 12 to 42 in. were installed. This water is continuously chlorinated with a dosage of approximately 5 p.p.m.

The industrial water system is completely independent of and is not used for any sanitary purpose. It has no physical connections with the town supply or any system used for washing, flushing, or drinking purposes. The pipe lines and valves are all painted a distinctive and distinguishing color and are lettered in accordance with an agreement with the State Department of Health of Maryland.

Elevated storage on the industrial water distribution system is provided by a tank of 750,000 gal. capacity.

During the past four years, the plant has performed consistently with no extraordinary difficulties other than those normally experienced with a water treatment plant. The turbidities have been under 10 p.p.m. and frequently under 5 p.p.m. The chloride content has averaged under 100 p.p.m. When short periods of excessive chlorides occur the water is bypassed and the open storage reservoir is used. The pH has varied between 6.6 and 6.8. Sulfates are less than 75 p.p.m. Methyl orange alkalinity shows wide fluctuations and at high figures requires doses of alum as high as 6 or 7 grains per gallon.

The bacteriological quality of the industrial water distributed in the plant has been consistently negative for coliform organisms in 1-ml. portions, and often negative in five 10-ml. portions.

Recurrent difficulties have been experienced with algae growths in the Humphreys Creek reservoir. These have been kept in check reasonably well by combined chlorine and copper sulfate treatment at frequent intervals.

The quality of water produced and the experience with its use has been so good since the construction of the plant in 1942 that the company decided to construct in 1947 an additional plant for the same purposes and at the same site with a capacity of 20 m.g.d. This plant is now under construction and on its completion by the end of 1947 the company will be in a position to produce a total of 65 m.g.d. This will be composed of 50 m.g.d. of chemically processed water of trickling filter plant origin and of approximately 15 m.g.d. of unprocessed activated sludge plant effluent, when the latter is available.

At the same time the company has negotiated a modification of its existing 50 m.g.d. contract with Baltimore City, raising the amount which the company can withdraw from the Back River Sewage Treatment Works to a maximum of 100 m.g.d., based on

TABLE I.—1946 Data on Reclamation of Sewage Effluents for Industrial Water Supply, Bethlehem Steel Co., Sparrows Point, Md.

Month	Volume (1,000 gal.)		Plant Flow (1,000 g.p.d.)	Chloride (p.p.m.)	Chemicals Applied			
					Alum		Chlorine	
	Trickling Filter Effluent	Activated Sludge Effluent			Pounds	G.p.g.	Pounds	P.p.m.
January	161,343	371,360	17,756	75	109,492	4.78	16,500	3.75
February	247,266	67,213	11,220	75	49,587	5.2	11,000	3.84
March	273,778	432,116	22,770	75	200,037	5.15	36,500	6.25
April	260,203	454,176	23,812	80	188,415	5.1	58,500	7.5
May	41,375	434,075	15,400	90	40,017	6.7	30,000	7.6
June	192,972	441,915	21,200	85	137,200	5.1	40,000	7.6
July	208,448	465,837	22,500	85	158,711	5.34	43,000	7.7
August	299,621	389,426	22,200	85	228,872	5.4	50,000	8.75
September	428,024	231,452	21,200	90	318,981	5.2	51,000	9.35
October	325,776	305,094	21,000	100	250,000	5.4	40,000	7.25
November	388,481	382,519	24,860	95	270,638	4.9	53,000	8.3
December	270,721	342,654	20,455	80	192,980	5.0	31,000	6.1

monthly averages. Approximately 100 m.g.d. will probably be used by the company, barring an economic recession, within the next three to five years. When this demand is reached a booster pumping station will be required on the main transmission line from the Back River Sewage Works to the Bethlehem Steel Company plant at Sparrows Point.

A summary of the industrial water use during 1946 is presented in Table I. The findings are typical of the usual results during the past five years of operation.

During 1946 the cost of this industrial water has been 1.73 cents per thousand gallons, exclusive of interest and amortization on the investment.

Agreement with Baltimore City

The Bethlehem Steel Company is responsible for financing all of the costs attendant upon processing, pumping, delivering and distributing the effluents from the Back River plant.

Baltimore City agrees to make available these effluents at the Back River Sewage Treatment Works. It will not expend any money in connection with this enterprise. The steel company built, maintains and operates all of the works necessary for the use of this supply. Its capital expenditures will be somewhat over $2,000,000.

Under the terms of the agreement between the city and the company, "The City will make every practicable effort to operate and maintain the Treatment Works and any additions thereto so that the effluent at the point of delivery to the Company shall have the following characteristics (to be tested from time to time in accordance with the most recent standard methods of water and sewage analysis prescribed by the American Public Health Association):

"(a) The hydrogen ion content shall not exceed 7.8 or fall below 6.5, calculated on the basis of monthly averages.

"(b) The total suspended solids shall not at any time exceed an instantaneous maximum of fifty parts per million and the monthly average of such solids shall not exceed twenty-five parts per million. This requirement shall not apply to effluent discharged from the secondary settling tanks connected with the trickling filter unit, which effluent shall not at any time contain total suspended solids in excess of an instantaneous maximum of

eighty parts per million and not exceeding, in monthly average, fifty parts per million.

"(c) The five-day twenty-degree Centigrade biochemical oxygen demand shall not exceed an instantaneous maximum of forty-five parts per million, and its monthly average shall not exceed twenty-five parts per million. This requirement shall not apply to effluent discharged from the secondary settling tank connected with the trickling filter unit, the five-day twenty-degree Centigrade biochemical oxygen demand of which effluent shall not exceed an instantaneous maximum of eighty parts per million, and the monthly average of which shall not exceed forty parts per million.

"(d) The chloride content shall not exceed one hundred seventy-five parts per million calculated upon the basis of monthly averages."

The company pays to the city the following sums of money for the use of the effluents, upon a graduated basis:

"(a) Fifteen days after the end of any month during which an average of less than twenty-five million gallons of effluent per day have been delivered to the Company, the sum of one thousand dollars ($1,000).

"(b) Fifteen days after the end of any month during which an average of twenty-five million gallons or more, but less than thirty-seven and one-half million gallons, per day have been delivered to the Company, the sum of fifteen hundred dollars ($1500).

"(c) Fifteen days after the end of any month during which an average of thirty-seven and one-half million gallons or more, but less than fifty million gallons, per day have been delivered to the Company, the sum of two thousand dollars ($2,000).

"(d) Fifteen days after the end of any month during which an average of fifty million gallons or more, but less than sixty-two and a half million gallons, per day have been delivered to the Company, the sum of twenty-five hundred dollars ($2500).

"(e) Fifteen days after the end of any month during which an average of sixty-two and a half million gallons or more, but less than seventy-five million gallons, per day have been delivered to the Company, the sum of three thousand dollars ($3,000).

"(f) Fifteen days after the end of any month during which an average of seventy-five million gallons or more, but less than eighty-seven and a half million gallons, per day have been delivered to the Company, the sum of thirty-five hundred dollars ($3500).

"(g) Fifteen days after the end of any month during which an average of eighty-seven and a half million gallons or more, but less than one hundred million gallons, per day have been delivered to the Company, the sum of four thousand dollars ($4,000)."

The agreement further provides that a minimum payment, however, shall always be made by the company, whether it uses the effluent or not, of the sum of five hundred dollars ($500) per month.

The city handles the sludge produced by the company processing plant on a monthly graded payment by the company.

Studies of the Baltimore Sewer System

One of the major difficulties encountered with the use of these effluents was in the chloride content of the sewage. It is surprising how meager the information on this score is in the Baltimore City sewage analyses as well as in most of the important plants of the United States.

Detailed studies of this particular characteristic had been carried out by the company over a period of almost 12 months on both influent and effluent liquids of the Baltimore City plant. These have been made continuously

during stated intervals each day and for every day in the month for a period of almost 12 months.

The average chloride concentration of the final sewage works effluent was between 125 and 150 p.p.m. It frequently dropped to below 100 and on occasions rose to 600 p.p.m., although for a very short period.

Since it is important for the company to have processed water in which the chloride content is kept at a minimum, a detailed survey by the company was undertaken for many months, of the entire sewage collection system of the city. As might have been anticipated, it was found that that part of the sewer system of the city which collects sewage from domestic areas showed chloride concentrations of less than 40 p.p.m.

The high concentrations almost invariably occurred in the low-level collection and interception system, providing service for the industrial and commercial areas of the city. In parts of this system chloride concentrations as high as 3,500 p.p.m. were encountered.

These are intermittent and difficult to detect, but they have been gradually isolated. Some of them are due to industrial processes, such as meat pickling and packing, the salt pickling of hides, the salt water discharges from zeolite water-softening plants, and to harbor water infiltration in breaks in low-lying sewers.

Some of these sources have been eliminated. Some continue to discharge into the sewers. Peak concentrations in excess of 175 p.p.m. have been sufficiently reduced so that the concentration of chlorides has been kept below the level of danger at the steel plant.

As far as the author is aware, this is the first known comprehensive survey of a large municipal sewer system with the intent of disclosing the sources of high chloride concentrations as a preliminary to the gradual elimination of the more important of them. The effort may inspire other communities to gather and make available information on chlorides and other ingredients of sewage, which are more important in industrial water use than for the current control of sewage effluent discharge into receiving bodies of water.

Acknowledgments

Mr. S. J. Cort is General Manager and Mr. Thomas Wilson is Chief Engineer of the Bethlehem Steel Company Plant at Sparrows Point, Maryland. The Chief Engineers of Baltimore City during the period of negotiations were respectively the late Mr. George Cobb and Mr. Nathan L. Smith. Mr. George E. Finck is Sewerage Engineer of the city of Baltimore.

Messrs. L. F. Coffin and William P. Hill, with their associates William A. Hazlett and John L. Hellman, of the operating staffs of the Bethlehem Steel Company, shared in all of the details of the development of this industrial water program.

The detailed drawings and specifications for the system as outlined were prepared by Whitman, Requardt and Associates, Consulting Engineers.

The author has been consulting engineer to the Bethlehem Steel Company in the selection of the industrial water project, in its design and construction, during operation of the completed system, in the development of additions to the project in 1947 and in the detailed negotiations on contractual arrangements with the city of Baltimore. Messrs. John C. Geyer and Herbert L. Weaver have at various times participated in the studies under the direction of the author.

The State Department of Health of Maryland, through the sympathetic cooperation of its Chief Engineer, George L. Hall, and his staff, did much to smooth out many steps which might otherwise have retarded the installation.

INDUSTRIAL WATER SUPPLY FROM PROCESSED SEWAGE TREATMENT PLANT EFFLUENT AT BALTIMORE, MD.— A DISCUSSION

By R. F. Goudey

Sanitary Engineer, Los Angeles, Calif.

Dr. Wolman has described and reported on a full year of operation of the largest installation of an industrial water supply derived from sewage effluents that can be found in the United States, or probably in the entire world.

The project is an epochal milepost in the conservation of water supplies. It establishes a policy of paying for the water as if it were a water right, which so far has not been the practice with most cities dealing with reclamation. It also establishes the precedent of an industry taking water from a city and in using it outside the city limits. It voids the city of Baltimore of any legal liability or responsibility for any adverse experiences of the company in connection with the use or the handling of the reclaimed waters.

The Baltimore agreement with industry establishes the principle that the company bear all of that additional cost of sewage treatment and reclamation over and above the cost of sewage disposal to the city if reclamation were not practiced. In other words, many new arrangements appear in the contract between the company and the city but all are logical, sound, and businesslike. Other communities attempting to practice sewage reclamation would do well to follow the legal implications as set out in the Baltimore contract.

In the West it is common to purchase water rights of good and inferior water for domestic, irrigation, and industrial uses, but the prices are usually much lower than the $3.00 per acre-foot rate for which the Baltimore contract provides. This high price of water right may be justified because of the guaranteed security of the reclaimed supply, its freedom from drought considerations, its superior mineral quality, and its far greater dependability over alternate ground water supplies. Sewage waters, as the population increases and the best waters continue to be used for domestic purposes, will always bring about improvements in the sewage quality because the ratio of sewage flow to infiltration will decrease. It will be interesting to note in other future sewage reclamation contracts whether a higher cost of water rights will prevail than for domestic waters.

The high capital cost of the industrial plant undoubtedly is a factor in determining water right costs and it is quite possible that future installations may not have to pay so much for water rights as in the case at hand.

The capital cost of developing the reclaimed water supply, however, is extremely low. In the West capital costs of water development works in the upper ranges may vary from $100,000 to $300,000 per sec.-ft. In the case at hand the comparable cost is but $26,000 per sec.-ft., which is well within reason.

It is refreshing to review the water quality standards set forth here because they are concise, restricted to a minimum number of specific requirements and are flexible. There should be little difficulty to both parties in complying with their responsibilities, which is bound to react in favorable public relations between the city and the company.

The total operating cost is given as $17.30 per m.g., but this cost includes the cost of pumping the reclaimed

water into the distribution system. The actual operation costs chargeable to sewage reclamation as a raw water supply are in the neighborhood of $10 per m.g.

In cases where industry actually takes less water than is represented by the total sewage flow, it would appear prudent for the company to divert its water at those times of the day when the quality of the water best suits its own interests and at those times of the day when the sewage can be treated most economically. By providing for a few hours' storage the company could divert all of the night flow and very little of the peak flow, which would greatly reduce operating costs of reclamation.

It is noted that chlorination equipment is provided at two different stages of the process, and that both installations are in duplicate. Such arrangements are seldom made but are an absolute necessity where it is really intended to control any possible health hazard. It is further noted that chlorination is being relied upon to control slime growths, which is a precaution usually neglected in domestic water supplies transported great distances where slime growths impair carrying capacity and produce objectionable tastes and odors.

AGRICULTURAL USES OF RECLAIMED SEWAGE EFFLUENT *

By L. V. Wilcox

Agronomist, Division of Soils, Fertilizers and Irrigation, U. S. Dept. of Agriculture, Riverside, Calif.

Irrigation has been practiced in various parts of the world since the beginning of recorded time. Some of the areas have failed while others are still in operation, notably on the delta of the Nile and along the lower reaches of the Euphrates. Irrigation in the United States, on a large scale, dates back less than a century. During this time several projects have been abandoned and small areas in nearly all projects have become unprofitable. The cause, in most cases, is an insufficient supply of irrigation water, or water of poor quality or inadequate drainage. In the early years, little attention was paid to the quality of the water diverted for irrigation use, but more recently much greater importance has been attached to the quality and, as a result, a considerable body of useful information on the subject is now available.

Use has been made of reclaimed sewage effluents for irrigation purposes for several decades. In some cases, the effluent is discharged directly into irrigation supplies, in others it is used to replenish the underground water by sinking it on pervious sands or gravels. In many instances, effluents have been used directly as irrigation water. Reasonable success has attended most of these operations and, in regions where water is the limiting factor in agriculture, the conservation and re-use of sewage effluents should be encouraged.

Sewage farming, as a method of sewage disposal, has been practiced in England and Germany for several centuries. Here in the United States, many cities have followed this method with varying degrees of success. Veatch (14) describes the practice, giving some information on the economics and the sanitary aspects together with a discussion of the experience of several cities. He states: ". . . sewage disposal by irrigation appears to be an acceptable method provided the raw sewage has adequate treatment and other conditions such as low rainfall, sandy soil and cheap land, are favorable." Obviously, factors that would militate against success are high rainfall, soils of low permeability and a short frost-free period. The experiences of four cities are described by Veatch. Tucson is particularly well situated having ample soil of high permeability; the climate is dry with high summer temperatures and low rainfall. The soil does not freeze and the growing season varies from 8 to 10 months. The project at Tucson is reported to be successful from the public health standpoint and economically sound. The installation at Lubbock, Texas, has not been as satisfactory, according to Veatch, as the one at Tucson, possibly due in part to a higher annual rainfall and a shorter growing season. The effluent from the Pomona, Calif., plant has been used successfully for irrigation for many years. It is discussed in some detail below. The effluent from

* Presented in symposium "Reclamation of Sewage Effluents" at 20th Annual Meeting of the Federation of Sewage Works Associations, in joint session with the American Water Works Association; San Francisco, Calif.; July 23, 1947.

the Denver sewage treatment works is diluted and used for irrigation during the growing season and diverted for storage during the winter.

Sewage farming, as such, is essentially a part of the sewage disposal process but the disposition of reclaimed effluents for irrigation use falls more nearly into the category of marketing a by-product. This paper considers the use of reclaimed effluents as irrigation supplies.

The purposes of this paper are: (1) to define the properties that determine the quality of the water for irrigation use, (2) to describe typical irrigation waters and (3) to discuss the effect of contaminants in an effluent on its use for irrigation.

Review of Literature

Hutchins (5), in 1934–37, made a study of sewage irrigation in the western states. He discussed the extent of the practice at that time as well as the sanitary and the economic aspects. A reasonably complete bibliography, covering the use of sewage effluents for irrigation, is included. Stokes (13) *et al.* compared sewage effluent with city water for use in the irrigation of Napier grass and Japanese cane. Analyses of effluents from ten sewage treatment plants in southern California are reported by Scofield (7, 8). These analyses, together with several thousand analyses of surface and underground waters, were made by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Division of Water Resources, California Department of Public Works, in connection with the South Coastal Basin Investigation. Other papers dealing with the quality of water for irrigation use are: Eaton (3); Eaton, McCallum and Mayhugh (4); Scofield (9, 10), and Scofield and Wilcox (12).

Methods and Accuracy

Careful analyses of representative water samples are essential to an understanding of the effect of irrigation waters on both soils and plants. Methods such as those described in *Standard Methods for the Examination of Water and Sewage* (1) or *Methods of Analysis—AOAC* (2), or "Methods of Analysis Used in the Rubidoux Laboratory*" are suitable. It is convenient to express the results in equivalents per million for the anions and cations, and in parts per million for boron and dissolved solids.

Dissolved Constituents and their Significance

The fund of information regarding natural waters is so much greater than that pertaining to sewage effluents, that for purposes of illustration the discussion that follows will deal with natural irrigation sources. The principles involved are the same whether the water used is from surface sources, wells, or sewage effluent.

The constituents that ordinarily are found in natural waters can be grouped under three headings. Group 1 includes the constituents that appear in low concentration, such as boron, silica, fluoride, nitrite, sulfide, phosphate, iron, aluminum, ammonia, hydrogen ion as measured by pH, and organic matter. Group 2 includes the cations: calcium, magnesium, sodium and potassium; and the anions: carbonate, bicarbonate, sulfate, chloride and nitrate. In Group 3 are the total salts determined by specific electrical conductance, total anions (or cations) and dissolved solids.

Group 1

Of the constituents listed under Group 1, boron is the most important

* Wilcox, L. V., and Hatcher, J. T. "Methods of Analysis Used in the Rubidoux Laboratory, Riverside, California." Ed. 5, U. S. Dept. Agr., Bur. Plant Indus., Div. of Soils, Fert. and Irrig. 1947. (Mimeographed.)

from the viewpoint of quality for irrigation use. Boron, in low concentration, is a normal constituent of most natural waters and occasionally it occurs in such quantities as to be injurious to crop plants. These facts were first reported by Kelley and Brown (6) as a result of investigations in 1926 and 1927. Subsequent studies by the U. S. Bureau of Plant Industry (3, 4, 12) confirmed the findings of Kelley and Brown and extended the observations to include most of the irrigated areas of the West. Boron, in concentrations less than 0.5 p.p.m. of the element, is thought to be safe for use on any crop. Concentrations in excess of 1.0 p.p.m. B will cause easily recognized injury to the more sensitive plants while concentrations of from 3 to 4 p.p.m. B are about the top limit for use on even the most tolerant crops. In a subsequent paragraph there are listed the common agricultural crops in the order of tolerance to boron.

Nitrite, sulfide and ammonia are found in poorly aerated waters and in low concentrations are not particularly objectionable in irrigation water. Iron, aluminum and phosphate are ordinarily present only in traces in the mildly alkaline waters of the West. Waters of high pH, *i.e.*, above pH 9, are usually unsuitable for irrigation use.

Group 2

The concentration and relative proportion of the several cations and anions in Group 2 determine, to a large extent, the character of a water. Calcium plus magnesium in excess of sodium is characteristic of a hard water and the converse, with sodium in excess, a soft water. A hard water will tend to keep the soil open and permeable and in good tilth, while the use of a soft water produces undesirable soil conditions such as poor tilth, low permeability and alkali. Scofield and Headley (11) summarized the results of a series of reclamation experiments in the frequently quoted statement: "Hard water makes soft land and soft water makes hard land." Potassium is usually present only in low concentrations. It is an essential plant nutrient and is therefore desirable. Its reaction with the soil is similar to that of sodium but less pronounced.

Of the anions, carbonate and sulfate form sparingly soluble salts with calcium. These salts, limestone and gypsum, are desirable soil constituents and are often added as soil amendments. The chlorides are soluble and characterize many saline waters and soils. Nitrate seldom appears in natural waters in more than traces. It is one of the major plant nutrients and is limiting in most of the arid regions. Sewage effluents often contain substantial quantities of nitrates and are therefore valuable for this reason.

Group 3

Group 3 considers the three measures of total concentration, conductance, total anions (or cations) and dissolved solids. For irrigation water analyses, the specific conductance measurement is generally used. A large proportion of the inorganic salts dissolved in a water is ionized. These ions can conduct an electric current and use is made of this property in the conductance determination. The electrical resistance, between platinum electrodes, is measured with a Wheatstone bridge using a previously calibrated electrode. From this value, the specific electrical conductance ($K \times 10^5$ at 25° C.) is calculated. It is a physical measurement of high precision that correlates better with plant response than either total anions (or cations) or dissolved solids. There is no simple relationship between the three methods of expressing total concentration. For natural waters, of the type used for irrigation, the fol-

lowing give approximately correct values:

$K \times 10^5$ multiplied by 7 = D.S. in p.p.m.

$K \times 10^5$ divided by 10 = e.p.m. anions (or cations)

Permissible Limits of Concentration

In setting up limits of concentration, it should be noted that there are many factors other than concentration that contribute to the success or failure of an irrigation enterprise. Of great importance among these is the permeability of the soil. Saline conditions will develop even with good irrigation water in a poorly drained soil and, conversely, fairly saline waters are used successfully on well-drained soils. Other factors of importance are: quantity of water used, method of irrigation, rainfall, climate, soil management practices and crop species. In using the limits suggested below, average conditions are assumed.

The three characteristics usually specified in tables of limits are: total concentration expressed in terms of conductance or dissolved solids in parts per million (p.p.m.); per cent sodium and boron in p.p.m. B. Per cent sodium is defined by the expression:

$$\text{Per cent sodium (\% Na)} = \frac{\text{Na} \times 100}{\text{Ca} + \text{Mg} + \text{Na} + \text{K}}$$

where the concentrations are expressed in equivalents per million (e.p.m.).

Table I gives the permissible limits for total concentration, per cent sodium and boron as suggested by Scofield (9).

The order of tolerance, suggested by Eaton (3) is shown in Table II.

Typical Irrigation Waters

For purposes of comparison with analyses of sewage effluents, there are presented in Table III the analyses of a number of surface waters. These are typical of the natural waters of the West and all have been used for irrigation for many years. Surface waters vary considerably depending upon the flow so that the analyses should be recognized as representing conditions at the time the samples were taken but not necessarily the high or low extremes. Except as noted, the analyses were made by the Rubidoux Laboratory of the U. S. Bureau of Plant Industry.

The first five analyses of Table III represent waters of low total salinity and are low in boron and per cent sodium as well. These are excellent irrigation waters. Analysis 6 is from Cache Creek in northern California and is characterized by its high boron content. This water causes injury to boron-sensitive plants but is satisfactory for tolerant crops such as sugar beets and alfalfa.

The next three, the San Joaquin, the

TABLE I.—Permissible Limits for Total Concentration, Per Cent Sodium and Boron in Several Classes of Irrigation Water

Classes of Water	Total Concentration as		Per Cent Sodium (% Na)	Boron (parts per million)		
				Crops Group		
	Conductance ($K \times 10^5$ at 25° C.)	Dissolved Solids (p.p.m.)		Sensitive	Semi-tolerant	Tolerant
Excellent, less than	25	175	20	0.33	0.67	1.0
Good	25– 75	175– 525	20–40	0.33–0.67	0.67–1.33	1.0–2.0
Permissible	75–200	525–1400	40–60	0.67–1.00	1.33–2.00	2.0–3.0
Doubtful	200–300	1400–2100	60–80	1.00–1.25	2.00–2.50	3.0–3.75
Unsuitable, more than	300	2100	80	1.25	2.50	3.75

TABLE II.—Relative Tolerance of Crop Plants to Boron[1]

Sensitive	Semi-tolerant	Tolerant
Lemon	Lima bean	Carrot
Grapefruit	Sweet potato	Lettuce
Avocado	Bell pepper	Cabbage
Orange	Tomato	Turnip
Thornless blackberry	Pumpkin	Onion
Apricot	Zinnia	Broad bean
Peach	Oat	Gladiolus
Cherry	Milo	Alfalfa
Persimmon	Corn	Garden beet
Kadota fig	Wheat	Mangel
Grape (Sultanina and Malaga)	Barley	Sugar beet
Apple	Olive	Palm (*Phoenix canariensis*)
Pear	Ragged Robin rose	Date palm (*Phoenix dactylifera*)
Plum	Field pea	Asparagus
American elm	Radish	Athel (*Tamarix aphylla*)
Navy bean	Sweet pea	
Jerusalem artichoke	Pima cotton	
Persian (English) walnut	Acala cotton	
Black walnut	Potato	
Pecan	Sunflower (native)	

[1] In each group the plants first named are considered as being more sensitive and the last named more tolerant.

Arkansas and the Rio Grande, are waters of moderate salinity. These streams, in the upper reaches, are of low salinity but these samples were collected at sites within or below the irrigated areas that are influenced by drainage return flow. Such waters are satisfactory on well-drained land but difficulty is encountered if drainage is impaired. The next (No. 10) is a representative analysis of Colorado River water as delivered to the Imperial and Yuma Valleys since the completion of Hoover Dam. The boron and per cent sodium are low and it is a satisfactory water on permeable soils.

Gila River water (No. 11) has a higher total salinity and sodium percentage and is, characteristically, a chloride water as differing from the Colorado which is a sulfate water. This water is used on well-drained soils without much difficulty but on heavier soils deflocculation and impermeability often develop.

The last analysis is from the Pecos River and represents the water available for irrigation in the Pecos and Barstow areas. The choice of crops is limited to the more tolerant species and farming is confined almost wholly to the light, well-drained soils.

Sewage Effluents as Irrigation Water

As noted above, there are reported in Bulletin 40A (8) of the California Division of Water Resources, several analyses of effluents from ten sewage treatment plants in southern California. These analyses include the determination of boron as well as a reasonably complete mineral analysis, and will serve to illustrate the methods used in classifying waters. Table IV shows the essential features of some of the analyses. In each case, in order to indicate something of the extremes, the high and low values, as measured by conductance, are shown.

It is not possible to make a close comparison between the composition of the input water and the sewage effluent. In most cases the city water comes from several sources and is correspondingly variable in composition. It is evident, however, that the efflu-

TABLE III.—Chemical Analyses of Important Streams from which Water is Diverted for Irrigation

No.	Stream	Conductance ($K \times 10^6$ at 25° C.)	Boron (p.p.m.)	Per Cent Sodium	pH	Silica (p.p.m.)	Calcium (e.p.m.)	Magnesium (e.p.m.)	Sodium (e.p.m.)	Potassium (e.p.m.)	Total Cations (e.p.m.)	Carbonate (e.p.m.)	Bicarbonate (e.p.m.)	Sulfate (e.p.m.)	Chloride (e.p.m.)	Nitrate (e.p.m.)	Total Anions (e.p.m.)
1	Yakima[1]	11.7	0.02	23	7.6	19	0.56	0.35	0.28	0.04	1.23	0	1.00	0.07	0.15	tr.	1.22
2	Sacramento[2]	15.0	0.05	18	7.9	25	0.63	0.51	0.26	0.04	1.44	0	1.22	0.13	0.12	tr.	1.47
3	Columbia[3]	15.1	0.05	13	7.0	—	0.90	0.39	0.19	—	1.48	0	1.26	0.21	0.07	tr.	1.54
4	Yellowstone[4]	19.1	0.06	29	7.5	—	0.89	0.59	0.61	0	2.09	0	1.18	0.52	0.10	0.03	1.83
5	North Platte[5]	28.0	0.03	22	7.5	15	1.61	0.57	0.63	0.07	2.88	0	1.59	1.12	0.09	0.03	2.83
6	Cache Creek[6]	50.8	1.78	32	—	—	1.31	2.40	1.77	—	5.48	0.40	3.37	0.61	1.05	tr.	5.43
7	San Joaquin[7]	76.4	0.18	52	7.0	19	1.79	1.58	3.84	0.16	7.37	0	2.50	3.90	1.04	0.04	7.48
8	Arkansas[8]	93.3	0.08	25	8.2	22	5.06	2.66	2.63	0.21	10.56	0.05	2.70	7.39	0.47	tr.	10.60
9	Rio Grande[9]	112	0.20	50	8.3	41	4.14	1.49	5.77	0.21	11.61	0.25	3.33	4.97	3.02	0.03	11.60
10	Colorado[10]	117	0.16	39	7.8	—	5.06	2.30	4.70	—	12.06	tr.	2.52	7.16	2.30	0.03	12.01
11	Gila[11]	133	0.20	60	—	15	3.39	1.59	7.75	0.25	12.98	0.30	2.75	2.29	7.07	0.01	12.42
12	Pecos[12]	542	0.37	40	—	22	25.06	12.66	25.79	0.61	64.12	—	1.34	35.64	26.79	0	63.77

[1] Yakima River from main canal on Sunnyside Project; composite sample for August, 1943.
[2] Sacramento River at Tisdale, approximately 35 miles above Sacramento, July 13, 1945.
[3] Columbia River at Wenatchee, Wash., November 25, 1935.
[4] Yellowstone River from canal at Huntley, Mont., June 7, 1940.
[5] North Platte River from canal near Scotts Bluff, Neb., May 23, 1945.
[6] Cache Creek at Capay Dam, Yolo County, Calif.; composite sample for August, 1941.
[7] San Joaquin River near Vernalis, Calif., August 10, 1933.
[8] Arkansas River at point of diversion of Rocky Ford High Line Canal, Pueblo County, Colo., July 21, 1944.
[9] Rio Grande at El Paso, Texas; composite sample for August, 1945.
[10] Colorado River at Yuma, Ariz.; composite sample for August 1–10, 1942.
[11] Gila River at Ashurst-Hayden Dam, Ariz., August 2, 1933.
[12] Pecos River near Orla, Texas, 19 miles downstream from Red Bluff Dam; composite sample for August 1–10, 1943. Analysis by U. S. Geological Survey (Water-Supply Paper 970, p. 70).

TABLE IV.—Analyses of Effluents from Sewage Treatment Plants in Southern California (8)

Description	South Coastal Basin Laboratory No.	Date	Conductance ($K \times 10^6$ at 25° C.)	Boron (p.p.m.)	Per Cent Sodium	Equivalents per Million						
						Calcium	Magnesium	Sodium[2]	Bicarbonate	Sulfate	Chloride	Nitrate
Los Angeles County Sanitation District Sewage Treatment Plant, Harbor City; discharge 15–20 c.f.s. Method of treatment: Imhoff tanks followed by treatment by activated sludge process, effluent chlorinated. Effluent discharged into Nigger slough.	3464[1]	11/ 1/30	133	0.46	61	3.64	1.97	8.75	8.00	2.50	3.86	—
	3829[1]	3/ 3/31	186	0.76	70	3.44	2.22	13.17	8.95	4.18	5.70	—
	3916[1]	3/31/31	203	1.03	79	2.59	1.89	17.37	13.29	4.75	3.81	—
City of Whittier Sewage Treatment Plant; discharge 1.6 c.f.s. Method of treatment: Imhoff tanks, sprinkling filters and secondary tank. Effluent used for irrigation on sewer farm, surplus discharged into creek.	1637	12/30/32	72.3	0.29	40	2.74	1.23	2.61	3.65	1.10	1.10	0.73
	1636	12/29/32	88.9	0.33	52	2.79	1.07	4.22	3.75	1.15	2.45	0.73
	4484[1]	7/ 6/31	96.8	1.49	49	3.49	1.15	4.44	2.34	1.15	2.20	3.39
Pasadena Sewage Treatment Plant; discharge 12–14 c.f.s. Method of treatment: fine screening followed by treatment by activated sludge process, effluent chlorinated. Effluent discharged into Rio Hondo.	1607	12/16/32	70.3	0.45	59	1.45	1.07	3.63	2.61	0.75	2.06	0.73
	2233[1]	1/ 2/30	77.3	0.35	55	1.95	1.07	3.63	3.51	0.83	2.31	—
	1604	12/15/32	82.2	0.50	65	1.60	1.07	4.95	3.80	0.96	2.71	0.15
City of Pomona Sewage Treatment Plant; discharge approximately 1.5 c.f.s. Method of treatment: Imhoff tanks followed by treatment by the activated sludge process, effluent chlorinated. Effluent used for irrigation.	1627	12/27/32	66.7	0.28	48	2.05	0.90	2.77	1.75	0.58	1.66	1.73
	3197[1]	8/22/30	70.3	2.84	52	1.75	0.82	2.83	2.85	0.60	1.95	—
	2147[1]	12/10/29	83.4	1.25	64	2.25	0.41	4.74	3.88	0.62	2.90	—

[1] Rubidoux Laboratory numbers.
[2] Alkali bases, by difference.

TABLE IV.—Continued

Description	South Coastal Basin Laboratory No.	Date	Conductance ($K \times 10^5$ at 25° C.)	Boron (p.p.m.)	Per Cent Sodium	Equivalents per Million						
						Calcium	Magnesium	Sodium[2]	Bicarbonate	Sulfate	Chloride	Nitrate
Orange County Cities Joint Outfall Sewer System; discharge 7 c.f.s. Waste Water Disposal Co. discharges into sewer system. Method of treatment: pre-chlorination and fine screening. Effluent discharged into ocean.	1644	12/28/32	261	1.88	76	3.49	2.47	19.39	9.60	1.17	14.58	—
	1643	12/28/32	395	3.52	83	3.84	2.63	31.41	9.34	1.02	27.52	—
	1648	12/30/32	570	5.74	85	4.49	3.62	46.65	9.56	1.15	44.05	—
City of Corona Sewage Treatment Plant; discharge approximately 0.8 c.f.s. Method of treatment: Imhoff tank, sprinkling filters and sand beds. Effluent discharged into gravel beds in Temescal Creek Wash.	1638	12/30/32	102	0.80	29	5.39	1.07	2.65	4.95	1.98	1.89	0.29
	1639	12/30/32	128	1.31	70	2.69	0.99	8.69	8.90	1.35	2.12	—
City of Riverside Sewage Disposal Farm; discharge approximately 3.6 c.f.s. Method of treatment: settling in earthen basins and land disposal. Used for irrigation on sewer farm and surplus disposed of on land.	1719	2/ 3/33	88.2	2.80	31	1.30	4.93	2.74	6.20	0.60	2.17	—
City of San Bernardino Sewage Treatment Plant; discharge 4.7–6.3 c.f.s. Method of treatment: pre-chlorination, Imhoff tanks, sprinkling filters and final clarifier, effluent chlorinated. Discharged into Warm Creek and diverted by Riverside Water Co. canal.	696[1]	2/28/29	64.3	0.16	48	2.69	0.66	3.06	4.29	0.77	1.35	—
	749[1]	3/13/29	72.8	0.21	43	2.79	1.07	2.86	4.34	0.58	1.80	—
	3348[1]	9/30/30	85.6	0.15	56	2.59	0.90	4.53	4.15	1.02	2.85	—
City of Redlands Sewage Disposal Plant; discharge approximately 1.2 c.f.s. Method of treatment: Imhoff tanks, followed by disposal on sand beds on north side of Santa Ana River Wash.	1718	2/ 3/33	91.5	10.64	67	2.00	0.99	6.08	6.85	0.42	1.80	—
	1717	2/ 1/33	99.7	4.76	66	2.20	1.07	6.45	6.85	0.42	2.45	—

[1] Rubidoux Laboratory numbers.

[2] Alkali bases, by difference.

ents are more concentrated than the input waters by at least two fold. It is also apparent that the concentrations of boron, bicarbonate and sodium in many of the effluents are disproportionately high. The high chloride content of the effluent from the Orange County Cities plant may be due to oil well brines from the Waste Water Disposal Company plant located east of Fullerton.

There is evidence of boron contamination in all of the effluents except from the Pasadena and San Bernardino plants. These latter two would be classed as good to permissible, according to the limits set up in Table I. The fact that relatively high concentrations of boron were found in the other eight sets of samples would render them questionable for irrigation use, even though the high values represent peaks of short duration. Such waters could probably be used safely if diluted with sufficient quantities of good waters.

Contaminants

The most common contaminant thus far encountered is boron. Solutions containing borax are quite generally used for washing citrus fruits in the packing houses. In some instances the waste solutions are emptied into the sewer. If the effluent is to be used for irrigation, separate disposal should be provided for such solutions.

It is assumed that most bactericides, fungicides, insecticides and herbicides, as well as certain plant hormones, salts of heavy metals and many organic chemicals would render effluents unfit for irrigation use. The bibliography by Willis (15) cites a number of papers pertinent to this subject. Specifically, it has been found that the following inorganic salts are toxic to plants: aluminum, lead arsenate, chromium in some forms, cobalt, copper, manganese, mercury, thallium and zinc. Great care should be exercised in permitting the disposal of trade wastes into sewer systems if the effluent is to be used for irrigation water.

Discussion

Reclaimed sewage effluents are used for irrigation purposes in many places. The effluent from domestic sewage is ordinarily safe for irrigation use, if the input water is good. Effluents containing trade wastes should be looked upon with suspicion, as many substances found in such wastes are toxic to plants. Effluents of this type can often be used if diluted sufficiently with good water. Because water is the principal factor limiting development in many parts of the arid regions, every effort should be made to prevent contamination and promote the use of effluents for irrigation purposes.

Summary

The properties that determine the quality of a water for irrigation use are discussed together with several examples of typical irrigation waters. The analyses of a number of sewage effluents are presented and the quality of such effluents is considered. Finally, a number of substances are listed that might possibly appear as contaminants in sewage effluents, and that are known to be toxic to plants.

References

1. "Standard Methods for the Examination of Water and Sewage." American Public Health Assn., Ed. 9 (1946), New York, N. Y.
2. "Official and Tentative Methods of Analysis." Association of Official Agricultural Chemists, Ed. 6 (1945), Washington, D. C.
3. Eaton, Frank M., "Boron in Soils and Irrigation Waters and Its Effect on Plants." U. S. Dept. Agr. Tech. Bul. 448 (1935).

4. Eaton, Frank M., McCallum, Roy D., and Mayhugh, Miles S., "The Quality of Irrigation Waters of the Hollister Area of California." U. S. Dept. Agr. Tech. Bul. 746 (1941).
5. Hutchins, Wells A., "Sewage Irrigation as Practiced in the Western States." U. S. Dept. Agr. Tech. Bul. 675 (1939).
6. Kelley, W. P., and Brown, S. M., "Boron in the Soils and Irrigation Waters of Southern California and Its Relation to Citrus and Walnut Culture." *Hilgardia*, 3, 445–458 (1928).
7. Scofield, Carl S., "Quality of Irrigation Waters." South Coastal Basin Investigation, Calif. Dept. Pub. Works, Div. Water Resources Bul. 40 (1933).
8. Scofield, Carl S., "Detailed Analyses Showing Quality of Irrigation Waters." South Coastal Basin Investigation, Calif. Dept. Pub. Works, Div. Water Res. Bul. 40–A (1933).
9. Scofield, Carl S., "The Salinity of Irrigation Water." Smithsonian Report for 1935, 275–287 (1936).
10. Scofield, Carl S., "Quality of Water of the Rio Grande Basin Above Fort Quitman, Tex." U. S. Geological Survey, Water Supply Paper 839 (1938).
11. Scofield, Carl S., and Headley, Frank B., "Quality of Irrigation Water in Relation to Land Reclamation." *Jour. Agr. Res.*, 21, 265–278 (1921).
12. Scofield, Carl S., and Wilcox, L. V., "Boron in Irrigation Waters." U. S. Dept. Agr. Tech. Bul. 264 (1931).
13. Stokes, W. E., Leukel, W. A., and Barnette, R. M., "Effects of Irrigation with Sewage Effluent on the Yields and Establishment of Napier Grass and Japanese Cane." Fla. Agr. Exp. Sta. Bul. 215 (1930).
14. Veatch, N. T., Jr., "The Use of Sewage Effluents in Agriculture." *Modern Sewage Disposal*, Federation of Sewage Works Assns., Chap. XVI, 180–190 (1938), New York, N. Y.
15. Willis, L. G., "Bibliography of References to the Literature on the Minor Elements and their Relation to Plant Nutrition." Chilean Nitrate Educational Bur., Inc., 120 Broadway, New York, N. Y. (1935).
Second Edition (1937).
Third Edition (1939).

AGRICULTURAL USES OF RECLAIMED SEWAGE EFFLUENTS—A DISCUSSION

By Dario Travaini

Superintendent of Sewage Treatment, Engineering Department, Phoenix, Ariz.

In the arid Southwest, water is the very basis of existence, and all water is valuable regardless of its sanitary quality. The great concern is to utilize every drop.

The main canals of an irrigated system should be considered as streams with controlled flow, taking the place of small rivers that flow through territory with more abundant rainfall. The water in irrigation canals in Arizona is usually of fairly good quality at the main diversion dams, but as it flows through miles of cultivated and populated areas, the water becomes polluted both bacterially and chemically.

Sewage effluents from complete treatment plants have delivered water for irrigation with less bacterial pollution than is found in many irrigation ditches. The Phoenix activated sludge plant effluent, when chlorinated, passed the U. S. Public Health Service bacterial standards for drinking water. When this chlorinated effluent was sold to the Roosevelt Irrigation District, it netted Phoenix $1.50 per acre-foot profit above expenses involved. It may be of interest to note that the highly polluted irrigation water in the Roosevelt Irrigation District ditch also passed bacterial drinking water standards below the junction with the chlorinated sewage treatment plant effluent.

Mr. Wilcox mentions that in regions where water is the limiting factor in agriculture, the conservation and reuse of sewage effluents should be encouraged. However, state boards of health usually frown on the use of

sewage effluents, regardless of the treatment, where crop control is impossible. By this is meant the irrigation of lettuce, celery, tomatoes, and other fruits and vegetables consumed without heat processing. The writer does not agree with the policy of allowing these same fruits and vegetables to be irrigated with grossly polluted irrigation water, or to allow them to be irrigated with diverted river flow below large cities, when during dry weather the flow may be practically all sewage or sewage treatment plant effluent.

This brings out the fact that up to the present time there is a lack of suitable criteria for establishing practical and uniform bacteriological standards for irrigation water and for sewage effluents to be used for irrigation.

The effect of chemical contamination of irrigation water on plant growth is also a problem of increasing concern. Mr. Wilcox has shown by careful investigation that some sewage effluents contain objectionable concentrations of impurities according to accepted chemical standards for irrigation water. Among these impurities are sodium and boron.

Without attempting to formulate any theories, here are presented a few facts observed in Arizona regarding the use of sewage effluents for irrigation. Normal sewage effluents, where used for irrigation, appear to contain certain constituents of distinct benefit to plant growth.

The cities of Prescott, Casa Grande, Chandler, Winslow, and Tucson have been using primary treatment plant effluents for years for irrigation. They all produce excellent yields of seed or fodder crops, or cotton.

The grounds of the Phoenix sewage treatment plant, irrigated with activated sludge plant effluent for the past fifteen years, has a luxuriant growth of vegetation. This same acreage, when regular irrigation water was previously used by Japanese in the raising of crops, was given up as a failure. The same effluent with no dilution diverted from Salt River by farming interests a few miles below the plant has grown bumper crops of higuera year after year without rotation of crops. The owners casually mention that the yield per acre is materially greater on the areas irrigated with the sewage effluent than their adjacent areas where regular irrigation water is used.

Recent investigations in the Salt River Valley by Harmon E. Keyes and associates have shown the feasibility of chemical conditioning of ordinary irrigation water to improve plant growth on arid soils. This is summarized here because of adaptability to sewage plant effluents. Use has been made of the cheap acid-iron salt combinations produced at the Phoenix sewage treatment plant (see THIS JOURNAL, May, 1947).

Iron sulfate, added to irrigation water, was shown to increase the content of iron, copper, manganese and zinc, which are micro-nutrient elements, on field tests with growing carrots. Mr. Wilcox has noted the poisoning effect of zinc, copper, and manganese on plants if these elements are beyond the tolerance limit of the plant. However, these elements are recognized as desirable constituents of vegetables when conditions are conducive to building these elements into plant structure in controlled amounts.

High sodium ratio has been considered in recent investigations to be a dominant factor in producing impervious soil conditions. It should be pointed out that this locking of sodium with soil colloids is attended by an alkaline soil condition. When this alkalinity is neutralized by acid the deleterious effects of "black alkali" are neutralized or destroyed.

Thus, one definite solution to alkalinity and sodium absorption effects is a suitable lowering of pH in the irrigation water. This can be effected by

direct addition of acid or iron sulfate. The economics of using these substances for agriculture have acquired a more favorable aspect since cheaper production methods have been made available.

Recent experiments conducted in Phoenix where mixtures of dilute digested sludge and ferrous sulfate were added to poor alkaline soil are showing marked stimulation of plant growth. A soil which would not satisfactorily support plant growth was treated with ferrous sulfate with the result that carrots are able to grow.

Before any conclusions can be drawn as to the use of sewage treatment plant effluents for irrigation, both the "pros" and "cons" should be weighed. Taking into account the deleterious elements which Mr. Wilcox has evaluated, the beneficial effect of favorable constituents of sewage effluents, particularly when treated with acidic iron sulfate, may throw the balance in favor of such effluents as compared to ordinary irrigation water. Quantitative evaluation of these factors will require extensive plant growing tests. The tolerance of various plants to known inhibiting chemicals may be increased by the growing zest imparted to plants by the favorable constituents of sewage effluents, particularly with possible addition of acid or iron salts when dealing with alkaline soils.

This all leads to the necessity for chemical and bacteriological standards for sewage effluents used for irrigation. It would be a great step forward if the Federation of Sewage Works Associations would take the lead in bringing about the establishment of such standards.

SOME ASPECTS OF THE REQUIREMENTS FOR THE QUALITY OF WATER FOR INDUSTRIAL USES*

By Sheppard T. Powell

Consulting Chemical Engineer, Baltimore, Md.

The variety of consumers of water for industrial purposes is so great, and the specific physical, chemical and bacterial requirements cover such broad limits, that no standard specifications for water quality are possible. In the industrial field, water should be considered as a raw material which must be processed to meet specific needs. It is obvious, even on casual reflection, that water suitable for one industrial process may be totally unsuited for the requirements of a dissimilar industry. Further, the demand for water of different quality in the same industry changes as the processes improve or develop. Since the selection and treatment of water in industrial processes are not subject to standardization, it is possible to discuss water quality only in general terms and to evaluate specific demands for certain purposes.

Due to the fact that stream pollution is becoming increasingly important with regard to its effect upon the quality of raw water, this is given consideration in the present paper wherever it is relevant to the subject under discussion. In many areas the problem is complicated not only because of the quality of the water available, but because of its scarcity. Securing of an ample supply of water, either from underground or surface sources, for large industries or in areas where there is great concentration of industrial development, often becomes an insurmountable task. It is for this reason that recourse has been made, in some cases, to the use of treated sewage and it is conceivable that the utilization of such waste water may increase as time goes on. Undoubtedly this source of water will solve many water shortages, but likewise may introduce new problems which will require solution to avoid costly operating difficulties.

American industry is often prone to undertake radical steps in matters of this kind without sufficient investigation or intelligent evaluation of the hazards involved. This paper has been prepared to present certain phases of the requirements of industry with respect to desired quality of water and to warn against the widespread use of sewage effluents until all engineering and economic phases of the undertaking have been surveyed.

Selective Uses of Water by Industries

There are so many uses for water in industry that a complete list of such requirements cannot readily be catalogued. It would be impossible to present in this paper specific chemical and bacteriological requirements in the great number of industries where water is essential for processing and other uses. The discussions will be limited to certain industries where the volume and quality of water become an all-important requirement. The operation of such industries, as related to their water supplies, is given merely to illustrate the problems, rather than to cover the entire field in this respect. In general, however, the

* Presented in symposium "Reclamation of Sewage Effluents" at the 20th Annual Meeting of the Federation of Sewage Works Associations, in joint session with the American Water Works Association; San Francisco, Calif.; July 23, 1947.

TABLE I.—Uses of Water in Industry

General Class	Typical Usage
Cooling Water	Surface condensers Heat exchangers Jet condensers
Processing	Water entering product Supplementary use in the manufacture of the product, such as washing, etc.
Boiler Feed	Steam generation
Sanitary	Drinking water Showers, washroom and toilet facilities
Fire Protection	General fire protection Sprinkler systems
Air Conditioning	Humidification, cooling and washing
Miscellaneous Uses	Clean-up water Lawn sprinkling, gardening, etc.

major needs fall within one or more of the groups classified in Table I.

Cooling Water

The largest single use of water by industries is for cooling purposes. The volume and the temperature of the cooling supply are of the greatest importance and can be specifically evaluated on a dollar basis. These requirements take precedence over the quality of the supply, and rightly so; however, water quality cannot be ignored, especially when dissolved salts, gases or by-products which are present have an adverse effect on the heat exchange equipment.

Cold water is essential for many processes, especially in the chemical industries. The effect of temperature on the economic value of a water supply is a phase of water engineering of the greatest importance to industries. Recognition of this is reflected in a study of temperatures of industrial water supplies, published by the U. S. Geological Survey in 1925 (1). For many industrial uses the temperature of water is the governing requisite, and the selection of plant sites is based frequently not only on availability and volume of a water supply, but also on its temperature.

Table II contains the summer temperatures of well water, as delivered to consumers, at various locations in the country. Table III is a record of temperatures of surface waters for many cities in the United States. The temperature of surface supplies and well waters obtained from shallow depths approaches, and fluctuates with, the temperature of the air. The temperature of deep well supplies is relatively uniform.

A marked increase in the temperature of surface water, above that normally expected, is caused by the discharge of hot or warm wastes or cooling waters into rivers and lakes. In certain densely developed industrial areas this condition becomes pronounced. As an illustration of this, there have been plotted (Figure 1) the mean air temperatures and the corresponding

TABLE II.—Summer Temperatures of Municipal Water Supplies for Various Cities Using Wells as a Source [1]

Location	Temperatures (° F.) at Main Outlet			
	June	July	August	Sept.
Albuquerque	72.0	72.0	72.0	72.0
Aurora, Ill.	60.0	60.0	60.0	60.0
Camden, N. J.	58.0	58.0	58.0	58.0
El Paso	84.0	85.0	85.0	84.0
Fresno	72.0	72.0	72.0	72.0
Houston	84.0	84.0	84.0	84.0
Jacksonville	84.8	86.3	86.7	82.4
Kalamazoo	52.0	52.0	52.0	52.0
Lafayette, Ind.	53.0	53.0	53.0	53.0
Lansing, Mich.	57.5	58.0	59.0	59.0
Lincoln, Neb.	58.0	59.0	59.0	59.0
Lowell, Mass.	50.0	50.0	50.0	50.0
Madison, Wis.	53.0	52.0	52.0	53.0
Marion, Ind.	54.0	54.0	55.0	55.0
Montgomery, Ala.	70.0	70.0	71.0	71.0
Pensacola, Fla.	70.0	70.0	70.0	70.0
Peoria, Ill.	56.0	56.0	56.0	54.0
Pontiac, Mich.	55.0	55.0	55.0	55.0
San Antonio, Tex.	76.0	76.0	76.0	76.0
Sioux Falls, S. D.	55.0	55.0	55.0	55.0

[1] Data taken from "Surface Water and City Water Temperatures During the Summer," published in *Heating and Ventilating*, Jan., 1939; and U. S. Dept. of Commerce publication, "Effect of City Water and Sewerage Facilities on Industrial Markets," April, 1938.

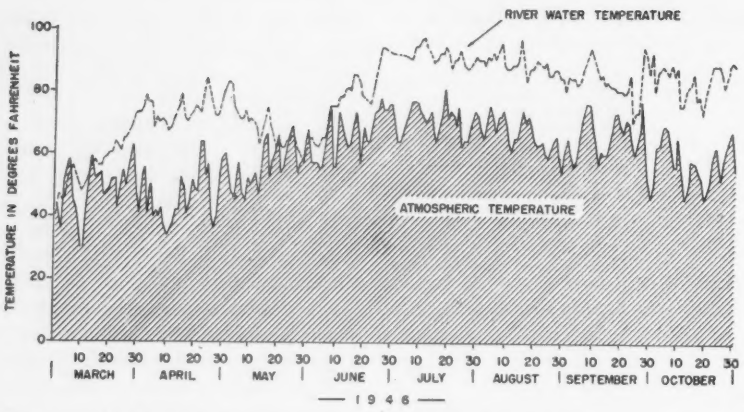

RIVER WATER TEMPERATURE
ATMOSPHERIC TEMPERATURE
TEMPERATURE IN DEGREES FAHRENHEIT
100
80
60
40
20
0
10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30
MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER
1946

FIGURE 1.—Relation of air temperature at Youngstown, Ohio and temperature of the Mahoning River water in the same area.

water temperatures of the Mahoning River at Youngstown, Ohio. This river flows through a highly industrialized section, and within a few miles, the river water is re-used for cooling water many times by a number of steel mills. From these records it is obvious that the thermal value of the water is materially depreciated for cooling purposes, especially when the temperature requirements of certain equipment must be limited to a specific range. Similar conditions exist in other industrial areas, and it is surprising that the problem has not received more attention, since it involves financial losses which can readily be calculated and related to plant efficiency and economy.

TABLE III.—Summer Temperatures of Municipal Water Supplies for Various Cities Using Surface Water Sources[1]

Location	Temperatures (° F.) at Main Outlet			
	June	July	August	Sept.
Atlanta	78.1	83.5	79.5	77.8
Baltimore	61.0	66.0	70.0	64.0
Birmingham	78.0	82.0	81.0	79.0
Boston	68.3	74.3	73.4	69.4
Buffalo	62.0	71.0	73.0	66.0
Chicago	55.4	68.0	69.4	62.5
Cincinnati	76.0	82.0	81.0	77.0
Cleveland	58.0	68.0	73.5	71.0
Detroit	64.0	75.0	74.0	68.0
Kansas City	84.0	93.0	91.0	85.0
Louisville	77.0	82.0	82.0	77.0
Nashville	84.0	88.0	88.0	84.0
New Orleans	86.0	89.0	90.0	90.0
Oakland	59.0	62.0	64.0	64.0
Philadelphia	71.0	79.0	77.0	72.0
Pittsburgh	75.2	80.6	80.6	75.2
Sacramento	70.7	70.7	80.6	77.0
St. Louis	77.0	85.0	83.0	75.0
Washington	43.0	67.0	73.0	75.0

[1] Data taken from "Surface Water and City Water Temperatures During the Summer," published in *Heating and Ventilating*, Jan., 1939; and U. S. Dept. of Commerce publication, "Effect of City Water and Sewerage Facilities on Industrial Markets," April, 1938.

For ordinary cooling and condensing operations the temperature of the available water supply may not be particularly important, but some processes have critical cooling water temperature ranges. The great demand for cold water to meet requirements has in some cases been responsible for over-concentration of industries in areas where cold underground waters are available. The partial or total exhaustion of such supplies is traceable to these heavy demands. Well failures of considerable magnitude are now occurring in many areas of the country. The depletion of ground water has made it necessary to utilize surface

water in ever increasing amounts and to resort to cooling towers and other facilities.

Recently, the author studied the water and temperature requirements for a large manufacturer. It was found that there was insufficient well water to meet the low temperature cooling water requirements, and the latter supply had to be augmented by refrigeration and a cooling tower. The estimated cost of the cooling tower equipment and the supplementary mechanical refrigeration to meet the plant requirements amounted to nearly half a million dollars. This condition was not due to increased temperature of the water because of industrial wastes discharged into the supply; however, the incident is related here to indicate the financial phase of the cooling problem.

Effect of Water Quality

The more important impurities in water which affect its utility for cooling purposes are scale-forming constituents (hardness), suspended matter, dissolved corrosive gases, acids, oil or other organic matter, and slime-forming organisms. Here again, well water is usually superior to surface water because it contains less suspended matter, dissolved oxygen and micro-organisms. However, in some areas the deep well water is very hard and contains iron, manganese, fixed sulfides or, occasionally, ammonia, the latter two being very corrosive to certain metals and alloys.

Surface water supplies used once-through for cooling, or water recirculated over cooling towers, may introduce problems related to all of the undesirable impurities listed above. Suspended solids in the cooling water are especially objectionable when they lodge on heat exchanger surfaces, since such materials, when accompanied by bacterial slimes and corrosion products, cause marked loss in cooling efficiency and accelerated corrosive attack on both ferrous and non-ferrous metals. Figures 2 and 3 illustrate respectively the condition of surface condensers when cooled by an untreated water and when cooled by a supply treated to prevent the deposition of solids.

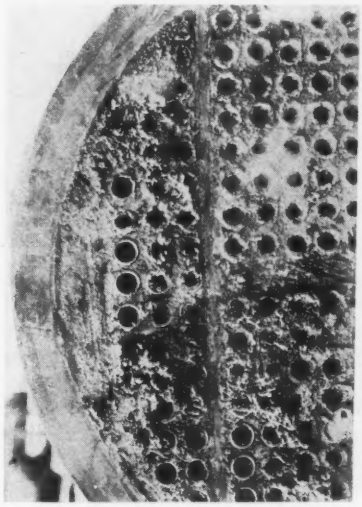


FIGURE 2.—Condenser cooled by untreated water.

The high temperatures in heat exchangers increase the rates of decomposition of organic compounds, slime growths, and gas formation.

Treatment methods are available to eliminate or minimize the ill effects of all of the impurities commonly encountered in underground, surface or recirculated water. Obviously, costs will limit the extent of treatment that is permissible and will dictate an arrangement of the water system to permit maximum re-use before discharge to waste.

Control of Corrosion and Scale

In an earlier paper (2) attention was directed to the difficulty of laying down a protective scale on tube surfaces when the cooling water supply was contaminated by slimes, algae and

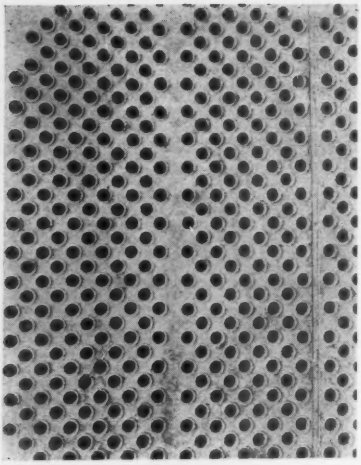


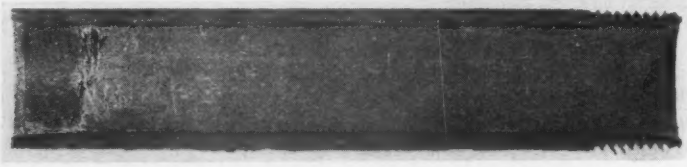
FIGURE 3.—Condenser cooled by treated water.

miscellaneous organic materials. The inhibiting effect of such pollutants is pictorially revealed in Figure 4. The lower specimen shows the corroded condition which occurred because of the failure to deposit calcium carbonate scale in the presence of organic inhibitors, while the specimen at the top of the photograph is from a tube which has been completely protected by a thin, hard, dense and adherent calcium carbonate coating. The deposition of this type of protective coating can only be obtained when the saturation index has been properly maintained and when no organic inhibitors are present in the water supply. These conditions illustrate the need for minimizing the organic contaminants in water which is to be conditioned to deposit protective coatings for prevention of corrosion in cooling water systems.

Process Water

As previously indicated, it is not possible in this paper to present a complete discussion of the requirements of the many water-using industries. This discussion is limited to a few of the more important ones to indicate the nature and extent of the problems encountered in these industries.

Water which is applied directly to the product must be treated selectively to meet the specific requirements of the particular product manufactured. Since the majority of manufactured



Specimen from adequately treated system. Note film of uniform, impervious protective scale.

Specimen from inadequately treated system showing some corrosive attack due to lack of uniform scale resulting from organic inhibitors such as algae and slimes.

FIGURE 4.—Corrosion test specimens showing results of adequate and inadequate controlled calcium carbonate scale treatment of recirculated cooling water supply.

products require different types of water, the characteristics of the raw water are not of prime importance except for their influence on the cost of treatment. It is obvious that the poorer the quality of the raw water, the more costly it will be to treat the supply.

Water for Paper and Textile Manufacturing

Ordinarily, water from underground sources is preferred to surface water supplies which are subject to contamination, but the very high demand for water in these industries frequently precludes the exclusive use of ground water because of the limited supply generally available from most water-bearing aquifers. In the larger plants, therefore, water from surface sources must be employed, and since it is seldom that these supplies are suitable in their raw state, treatment is required.

The most important requirements with regard to water quality in the paper and textile industry are freedom from color, turbidity and suspended matter, and there are also limitations on the content of hardness, manganese and iron. Control of slime formations, algae growths and various micro-organisms is commonly necessary in paper mills, especially where the raw water is heavily polluted.

Water softening and the removal of color, suspended matter, iron and manganese are readily effected by standard treatment and filtration facilities. However, all water conditioning is detrimentally affected when the water is contaminated by domestic sewage and industrial wastes. High concentrations of soluble organic matter greatly retard coagulation of color or turbidity as well as the softening reactions of the lime and soda process. Difficulty has also been experienced in the removal of iron and manganese in the presence of certain types of organic material.

If reasonably soft water is available for use in the textile industry, softening may not be essential, but this is seldom the case. For instance, in the processing of cotton fabrics, the material is boiled with an alkali to remove certain constituents in the fabric, particularly waxes and similar products. If hard water is used, the alkali solution (usually soda) results in the formation of calcium and magnesium salts, which are highly objectionable. It is particularly difficult to mercerize fabrics where hard water is used, because of the failure of adequate penetration of the dyes which are subsequently applied.

A few years ago widespread difficulty was experienced in one location in the textile and silk industries when a harder water supply was substituted for a relatively soft public water supply which had been treated to prevent corrosion by maintaining a high pH value. It was found that the hard water caused precipitation of salts in processing silk fibres and prevented the penetration of the weighing material into the fabric. Difficulty was also experienced in the woolen industry in the same area because of the detrimental effect of the hard water on some step in the processing of this material. The problem was overcome by reverting to the use of the original supply and selectively furnishing only certain industries with the hard water.

Pharmaceutical and Biological Requirements

Water entering pharmaceutical and biological products requires a higher degree of purification than is necessary in any other industry. Water for these purposes cannot be used satisfactorily as received from any of the ordinary sources available. Even with the most meticulous water conditioning operation involving clarification and softening, the water produced is still unsatisfactory for some of the more refined requirements in the industry in question.

Where water is to be used for the manufacture of serum, it must be "pyrogen-free." The term "pyrogen" is not widely recognized in the water works field, but is used to define specific requirements in the pharmaceutical industry. The definition of "pyrogen" is given in Stedman's Medical Dictionary as follows: "An agent which causes a rise in temperature." It is probable that the pyrogens are complex bodies induced by certain types of microscopic organisms, or possibly the products of bacterial metabolism. Although the nature and character of pyrogens are still in the "twilight zone" of exact knowledge, much study and research are being conducted to establish the character of these products.

As the result of recent research in this field, certain pyrogenic products formed by micro-organisms have been concentrated in sufficient amounts to permit them to be analyzed. This work has shown that they contain phosphorus, but one authority states that they "probably do not contain nitrogen or proteins, as they are believed to be of the sugar family, *i.e.*, carbohydrates." The art of recognizing and controlling pyrogens is now sufficiently advanced so that there is no longer danger of preparing serums which contain these materials.

It has been demonstrated that simple distillation does not destroy pyrogens and that they are carried over with the steam or vapor and reappear in the condensate. In solution they withstand the ordinary sterilizing procedures, and although they may be present only in infinitesimal quantities, they are not detected by the usual forms of analysis. Even when present in minute quantities, pyrogens can cause considerable physiological upset when they enter the blood stream. This may occur upon the injection of improperly prepared serums. During the war considerable information was gained regarding the action of these materials, because of the extensive use of blood plasma transfusions.

The sources of pyrogens are not entirely known but are probably very widespread, and they may be present both in the atmosphere and in water. Pyrogens, or the effect of pyrogens, can be minimized or eliminated at high temperatures, and it is reported that when exposed to a temperature of 464° F., their ability to cause fever disappears. Because of the serious difficulties resulting from the presence of pyrogens in the manufacture of serum and antitoxins, extreme aseptic conditions must be maintained.

To assure pyrogen-free water, users of such supplies depend on triple distillation, and in some cases complete demineralization of the water by means of ion-exchange equipment is practiced prior to distillation. One serum manufacturer has advised that the pyrogen-free water must be kept hot, since if this is not done, the pyrogens are again formed. A special asbestos filter has been developed which is reported to remove these materials. Further, many manufacturers treat the water in the stills with permanganate in order to destroy the pyrogens which otherwise would be carried over with the vapor.

To what extent the contamination of surface watercourses by domestic sewage or by miscellaneous industrial wastes increases the pyrogen content of the supply is not known, but it offers a fruitful field for research.

Treatment of Water for Steam Generating Purposes

During the past ten or more years, the specifications for the quality of water for boiler feedwater use have become increasingly exacting. This has been brought about by the installation of boilers designed to operate at high generating rates, which produce steam at greatly increased pressures and temperatures. A few years ago

it was current practice to operate boilers in the range of 250 to 450 p.s.i. At the present time a large number of units are installed which are operating at 1,000 p.s.i. Several boilers are now in service, or are in the process of construction, which will operate at 2,500 p.s.i. pressure. These conditions require a boiler feedwater of high purity in order to avoid costly maintenance or repairs. Further, the large investment for this type of steam generating equipment demands a minimum of outage. It is now common practice to keep boilers in contiuous service for a period of one to two years.

In central station practice employing steam turbines and surface condensers, very little new water or make-up is used, since practically all of the steam is condensed and returned to the boilers as feedwater. There is now a marked trend, however, toward the use of high-pressure steam plants in industrial establishments, and most of these require a large percentage of make-up due to the fact that large quantities of steam are consumed in process.

Because of these trends, the effect of sewage and industrial pollution upon surface supplies, which constitutes most of the raw water used for steam generation, is becoming increasingly more important. Organic contaminations which inhibit softening reactions are highly objectionable, since the pollutants may reach the boilers where they decompose and form products which become entrained in the steam, thus resulting in operating and maintenance problems.

TABLE IV.—X-Ray Identification of Deposits Which Have Been Removed from the Blading of Steam Turbines

Compound	Mineral Name	Formula
Calcium carbonate	Calcite	$CaCO_3$
Calcium carbonate	Aragonite	$CaCO_3$
Calcium aluminate		$3CaO \cdot Al_2O_3 \cdot 6H_2O$
Calcium phosphate	Phosphate	$Ca_3P_2O_8 \cdot H_2O$
Magnesium hydroxide	Brucite	$Mg(OH)_2$
Copper sulfite	Chalcocite	Cu_2S
Nickel oxide	Bunsenite	NiO
Silicon oxide	Quartz	SiO_2
Silicon oxide	Cristobalite	SiO_2
Silicon oxide	Opal	SiO_2
Sodium sulfate	Thernadite	$Na_2SO_4(V)$
Sodium-carbonate-sulfate	Burkeite	$Na_2CO_3 \cdot 2Na_2SO_4$
Sodium chloride	Halite	$NaCl$

Soluble silica is particularly detrimental, for it tends to form dense, hard scale on heating surfaces. This is true even when the silica is present in extremely low concentrations. There are many boiler scales of this type, the most objectionable ones being of the analcite series which, when deposited on metal surfaces receiving high heat input, cause damage in a short time. Boiler tube failure caused by this type of overheating due to scale is shown in Figure 5.

One of the most serious problems now facing the operation of central stations and industrial plants where high-pressure boilers are employed is the deposition of silica on the blading of steam turbines (Figure 6). No solution to this problem has yet been found and extensive research is under

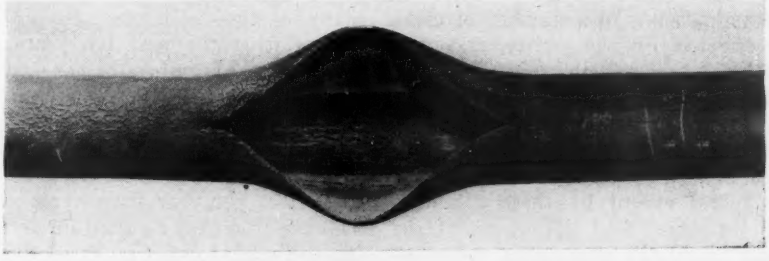


FIGURE 5.—Tube failure resulting from analcite scale.

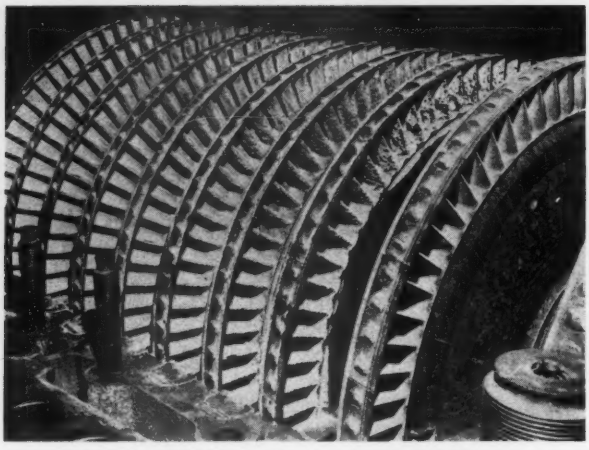


FIGURE 6.—Silicious deposits on turbine blading.

way in an effort to develop corrective measures. The siliceous material may be deposited in several forms. A list of the products is given in Table IV. These compounds, which are largely pure silica, are extremely difficult to remove from the blades. When the formations accumulate in sufficient amount there is considerable loss of capacity in the generating unit. If this condition reaches a critical stage, the siliceous deposits must be removed by backwashing with wet steam and caustic soda, or the unit must be taken out of service, completely dismantled, and the formations removed by blasting with fly ash or other materials.

All surface water supplies, in their natural condition, contain some silica, so difficulty from this constituent may exist regardless of industrial or sewage contamination. In a number of cases investigated by the writer, however, the condition of the deposition of silica in boilers and on turbine blading has been magnified as a result of contamination from waste products. The effect of such pollution is not ordinarily recognized except by those specializing in this field. However, these losses translated into dollar value involve great sums of money, and they are therefore of sufficient importance to demand recognition and corrective measures.

Because of the complexity of the subject, the foregoing discussion has been limited to general water quality requirements for boiler feedwater and the effect of pollution on the quality of supplies used for this purpose. The conditions and examples cited serve to illustrate the need for careful investigation and planning prior to the installation of high-pressure boilers and auxiliary equipment.

Observations of Ground Water

The exhaustion of underground waters by concentration of industries depending on such supplies is having marked repercussions in the industrial growth and future development in many sections. In the Texas City area, during the past ten years, the elevation of ground water has dropped and is continuing to fall at a rapid rate. The water level in deep wells is now receding at a rate of 23 feet per year, while shallow wells have lost 16 to 18 feet per year for several years. This condition has resulted in dewatering the sands to such an extent that at some points within this area the ele-

vation of the land has dropped as much as two feet.

During the war period, when heavy overdraught was imposed upon the water-bearing aquifers in the Louisville area because of the high concentration of industries (especially synthetic rubber plants) a serious condition arose. A number of emergency measures were required to insure the continuous operation of these plants because of their great importance to the war effort. Similar conditions are occurring in Southern California, Texas, Florida, and other locations. These problems clearly demonstrate the need for curtailment of withdrawal of underground waters and the need for increasing use of surface supplies to meet industry's requirements. It must be obvious that dependence on surface supplies requires a minimum of pollution loading to avoid serious operational problems to permit meeting the industrial and commercial requirements.

Concerning the exhaustion of wells in certain areas, some relief may be effected by recharging the aquifers with cold treated water during the winter months and using the cold water supply thus stored during the warm weather. Such replenishment of the underground supplies has been advocated by the U. S. Geological Survey for a number of areas where the underground water supplies are affected critically.

Replenishment or recharging in this way has merit, but it is imperative to use only water which is safe from a sanitary standpoint and which will be chemically compatible with the underground water so as not to affect adversely either the well supply or the water-bearing formation from which the water is drawn. Such operation requires a well-planned program and careful consideration of the economic and practical aspects to assure success. It has potential merit, since in many cases it may minimize or correct severe underground water shortages. Often it can be justified from the savings which can be effected by providing a continuous use of cold ground water in warm weather, eliminating the need for installing refrigeration.

Favorable results can only be secured by selective recharging of the aquifer with cold water. In at least one case the underground water supply was replenished by pumping warm water into the ground. In a short time the temperature of the entire underground water supply increased, and the recharging had to be curtailed due to the fact that the supply lost its thermal value.

Influence of Stream Pollution on Industrial Water Supplies

The pollution of surface water supply sources has become a problem of major magnitude, and legislative bodies have responded with a variety of control measures. Pollution loading on streams has a direct bearing on the type and design of water conditioning plants and on the investment required for the treating facilities and the cost of operation.

Industrial management has not fully realized the import of stream pollution with respect to its water requirements, and many processing difficulties due to contaminants in the water could have been relieved by adequate planning in the selection and treatment of the raw water. Lack of intelligent planning as to the availability of water and its pollution loading has been responsible for heavy financial losses by the industries affected. Mutual understanding and cooperation by groups of industries whose waste products, jointly or separately, detrimentally affect others, are urgently required. If cooperative planning is properly instrumented, it will bear fruitful results to all concerned.

Oil Contamination

Practically all surface waters receiving industrial wastes are contami-

nated by oil to some degree. In areas where petroleum refineries are located, contamination may be fairly extensive. Oil and grease contaminants are contributed also by vegetable oil processing plants, wool scouring operations, domestic sewage and other sources. Oily water may retard corrosion of metal in some instances, but waters contaminated by oil or grease are highly objectionable when used as cooling water for heat exchangers, surface condensers and similar types of equipment. The free oil present can be fairly readily removed by adequately designed and operated treating systems, but when oil is present as an emulsion or in combined form, it may pass through treatment plants.

No oil should be present in boiler feedwater. (Performance guarantees for modern boilers stipulate that oil in the concentrated boiler water shall not exceed 7 p.p.m.) Serious damage has resulted from only a few parts per million of oil in feedwater fed to high-pressure boilers. When oil is present in the feedwater it forms deposits on the boiler tube surfaces, preventing proper heat transfer, thus causing overheating and final failure of the metal.

The increasing demand for reduction of the amount of oil in waste waters is requiring the installation of oil removal systems not previously considered necessary. The type of equipment which has been most extensively used in the past, and which is still the most practical design to employ for this purpose, is that proposed by the American Petroleum Institute. The design of this equipment is shown in Figure 7.

The A.P.I. separator consists of two basins, connected in series, designed to effect gravity separation of oil from water with provision of mechanical equipment for removal of both separated oil and deposited solids. The basic features of design are directed toward agglomeration of small droplets of oil and maintenance of straight-line flow of liquid, with a minimum of turbulence that may interfere with the gradual rise or fall of particles that approach the specific gravity of the water in which they are carried. Units of this kind, when properly designed and operated, are quite effective in removing free oil but cannot be depended upon to remove oil in emulsified form.

In a recent investigation made by the author, it was found that at certain periods of operation the oil content leaving a standard A.P.I. separator was higher than could be considered satisfactory. A study in the plant showed that the oily wastes delivered from one operation were in a highly emulsified form, and this material, although relatively small in volume in proportion to total waste, resulted in poor operation of the A.P.I. separator. The problem was solved by treating the oily emulsion separately.

The treatment for breaking the emulsion consisted of coagulation with lime and an iron salt, and subsequent removal of demulsified and suspended oils by means of a Dorr clarifier. By operation of the combined systems, the refinery in question is now delivering, at all times, an effluent with an oil content not exceeding a range of 5 to 10 parts per million.

It is difficult to establish any maximum limit to the quantity of oil which should be permitted to be discharged into a surface water supply. It is practically impossible to so treat the waste water from a refinery or similar oil-producing industry that no oil will escape from such operations. Further, a fixed arbitrary standard may not be practical or reasonable. A fair and workable limit to be imposed on oil content must take into account the local conditions and an evaluation of the capacity of the receiving body of water to destroy or dissipate the oil which will be added. It is the author's

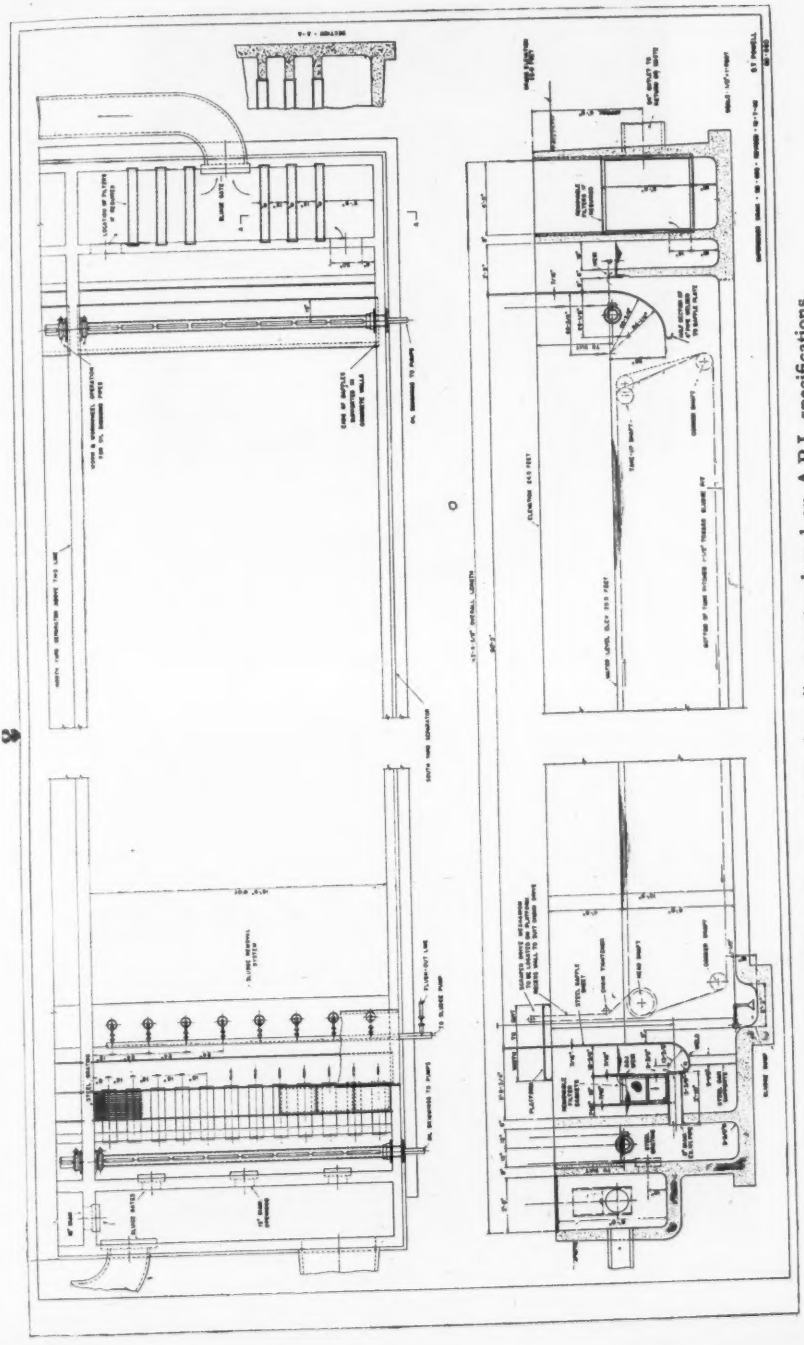


FIGURE 7.—Design of gravity oil separator based on A.P.I. specifications.

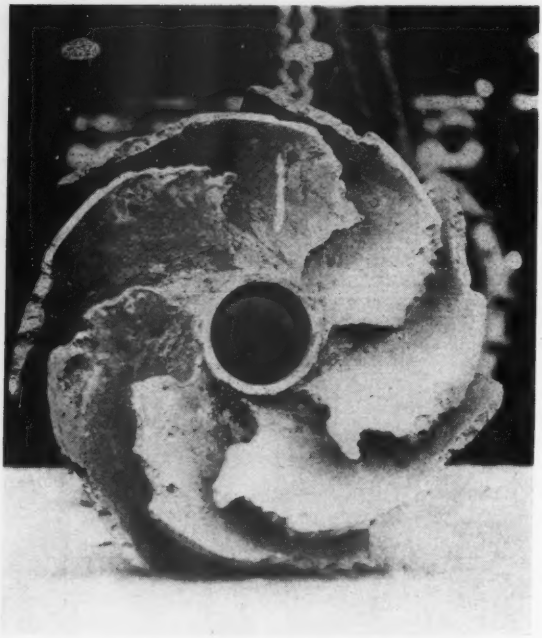
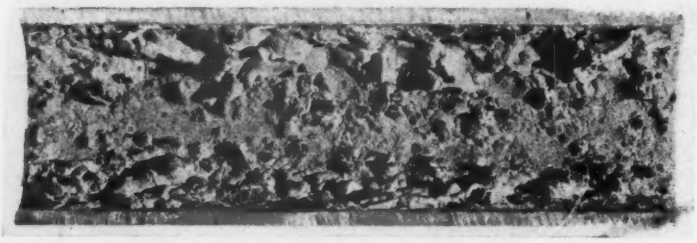


FIGURE 8.—Pump runner damaged by aggressive water.



Corroded section as removed from system. Note rust tubercles on internal surface.

Section after removal of rust tubercles. Note general pitting of the metal.

FIGURE 9.—Action of corrosive cooling water upon unprotected pipe line in service approximately 3 years.

belief that each case should be judged on its own merits and with due regard to the rights and requirements of all parties using the water jointly.

Corrosive Contaminants

The presence of acid wastes in water used by industry results in the rapid corrosion and destruction of pumps, heat exchangers and piping systems. In large plants such corrosion often involves many costly replacements. These conditions can be the result of inorganic acids or the decomposition of organic compounds. Figure 8 shows the attack on the runners of a cast iron pump, and Figure 9 is a photograph showing the rapid corrosion and attack on steel pipe due to a polluted water supply. The corrosive attack on the piping system of the plant could have been minimized by preventing the highly acid wastes from the plant of an adjacent industry from reaching the stream.

Ammoniacal contaminants in fairly dilute solution do not attack ferrous metal but may rapidly attack copper. When ammoniacal solutions are in contact with copper, a complex cuprous-ammonium ion is formed; the oxides of this ion are soluble and do not form a protective coating, and the metal is rapidly corroded and destroyed. Not only is copper attacked by ammonium salts, but many of the copper alloys are affected also. Yellow brass (Muntz metal) is rapidly dezinced when in contact with ammonia, and more resistant materials, such as Admiralty metal and other higher grade alloys, are rapidly corroded. The aggressiveness of such attack is illustrated in Figure 10 (several magnifications). This is a picture of a brass control element in a steam trap which was completely destroyed by corrosion in about three years because of the accumulation of ammonia released by the steam used for heating.

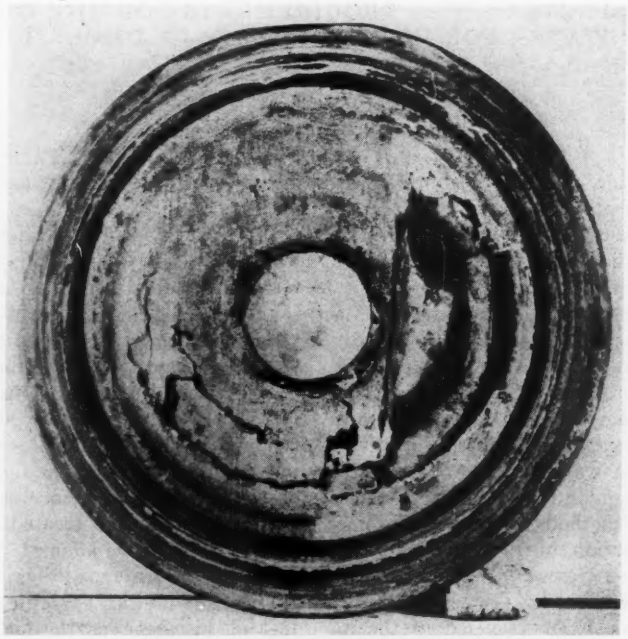


FIGURE 10.—Corroded trap element.

Heavy financial losses due to condenser tube failures have occurred and are still being experienced, because of the presence of ammonia and amino acids in water circulated through condensers and miscellaneous heat exchange apparatus in central power stations and other plants.

High ammonia content in water is often the result of contamination with domestic sewage, gas house wastes or coke-oven effluents. Waste from certain chemical plants often contains high concentrations of ammoniacal products. It is not possible to establish maximum limits for such constituents below which no difficulty will be experienced. Correction of the trouble rests largely on avoiding the discharge of high concentrations of such wastes into the watercourse, and the use of materials by designers and operators which will afford resistance against corrosive attack by the compounds present. Break-point chlorination can be used to remove ammonia and eliminate its attack on brass and copper; the suitability of such measures rests on the quantity of ammonia present and the resulting cost of treatment.

The most economical and intelligent approach for avoiding the corrosive attack on metal is to control the discharge of the wastes into waterways which are subsequently to be used by others. Mutual cooperation and understanding among industries should do much to relieve the existing stream pollution problems of this type.

References

1. Collins, W. D., "Temperature of Water Available for Industrial Use in the United States." Water-Supply Paper 520-F, U. S. Geological Survey.
2. Powell, Sheppard T., Bacon, H. E., and Lill, J. R., "Recent Developments in Corrosion Control." *Journal of the American Water Works Assn.*, **38** (July, 1946).

SOME ASPECTS OF THE REQUIREMENTS FOR THE QUALITY OF WATER FOR INDUSTRIAL USE—A DISCUSSION

By A. M. Buswell

Chief, Illinois State Water Survey, Urbana, Ill.

The writer does not wish to imply that the reclamation of sewage effluents is generally impracticable, but it is his opinion that such a procedure will not always be found profitable.

The re-use of process water by industry has been increasing rapidly during the last 25 years. In starch manufacture the steep water is now recycled completely. Paper mills and allied industries now recycle all of their white water. These procedures have been made possible by the development of methods to prevent the bacterial infection of process liquors to permit their re-use. Where water is used for extraction purposes, it may advantageously be recycled in the industry. Many cases exist in which more progress could be made in this direction.

While not intending to detract from what has already been said, the writer feels that some warning should be sounded concerning certain complications which may arise from the use of treated sewage. Dr. Mohlman has already referred to the various effects of nitrogen compounds. In general, the removal of B.O.D. from sewage does not result in a corresponding removal of nitrogen. Its presence as ammonia and nitrates in the treated effluent is many times the amount ordinarily found in the water supply.

One outstanding example of the effect of nitrates was the classical case of the Ulva trouble in Dublin harbor.

The treatment works for the city of Dublin, Ireland, turned out a water which was very high in nitrates. This stimulated such a luxuriant growth of Ulva, or sea lettuce, that the whole harbor became choked. The remedy in this case was to partially by-pass the filters, since the unoxidized forms of nitrogen did not stimulate Ulva growth.

The recent publications of Sawyer have discussed more fully the effect of phosphates as well as nitrogen in the stimulation of algal growths. It is also important to note that ammonia is a potential source of energy as well as nitrogen, and luxuriant bacterial growths may occur in the absence of sunlight where ammonia is present.

In many cases the small amount of organic matter remaining in effluents may produce surprising amounts of foam. This foam may or may not be seriously objectionable. At any rate, it is a telltale. The chloride increase from private zeolite softeners may be objectionable in some cases, since there is as yet no economical method of removing chlorides. In this connection the writer is reminded of a calculation made by Dr. Karl Imhoff some years ago, indicating that after seven-fold re-use for ordinary domestic purposes, the chloride content of a stream would be beyond allowable limits.

Color is another characteristic which tends to persist in treated effluent.

Mr. Powell's paper emphasizes the crux of the whole matter, namely, "What standards must be met if water is to be re-used for industrial purposes?" One may cite, for example, his statement that oil even in minute amounts is incompatible with the use of water for boiler purposes. This corresponds with the writer's experience in such matters.

In conclusion, the fact is emphasized that if sewage effluents are to be re-used there will have to be much greater uniformity in the operation of waste treatment plants than is generally obtained today. An effluent discharged into a stream or lake of relatively large capacity may vary in quality by perhaps several hundred per cent from time to time without causing detectable effects, but if such an effluent is to be re-used, the consumer will promptly note relatively small variations in quality.

SEWAGE TREATMENT AT MILITARY INSTALLATIONS—SUMMARY AND CONCLUSIONS *

By the NRC Subcommittee on Sewage Treatment

Gordon M. Fair
Ralph E. Fuhrman
C. C. Ruchhoft
Harold A. Thomas, Jr., *Secretary*
F. W. Mohlman, *Chairman*

Subcommittee of the Committee on Sanitary Engineering, National Research Council, Washington, D. C.

The original report of the NRC Subcommittee on Sewage Treatment in Military Installations was published immediately after completion in 1946 but without any critical summary or discussion. Comments and criticisms were requested, to be discussed in a later concluding chapter.

This summary report comprises an abstract of the most significant findings and the conclusions drawn from such findings, but does not include much, if any, of the discussion of the more abstruse conclusions based on research studies of the data, as contained in the original report. The summary includes practically all of the conclusions of the original report which relate to practical questions of operation, as well as general deductions from the data on processes of treatment; also recommendations as to design, operation and management of future military treatment works; and several references to comments or criticisms received after publication of the original report. Comments from the Office of Chief of Engineers will be discussed with the OCE directly, but are not published here. Some additional comments or discussions received have not been considered to merit publication, except a discussion dealing with filters that was submitted by Mr. E. S. Rankin.

SUMMARY OF REPORT

General Considerations

Sewage treatment in World War I included use of septic tanks, Imhoff tanks, trickling filters, contact beds and intermittent sand filters. The septic tanks were horizontal flow single-story tanks known as "Construction Division" septic tanks. There were several sludge compartments, equipped with draw-off pipes. Under-and-over baffles were provided and the final design included capacity for a period of 2 hours at 20 gal. per capita per day, after scum had accumulated. Frequent removal of malodorous sludge was necessary.

"On the whole the 'Construction Division' septic tank was generally unsatisfactory. Separation of sludge proceeded on a 'flotation' rather than a 'sedimentation' principle. Sludge was voluminous, greasy, undigested and slow-drying."

In contrast, Imhoff tanks performed well, but sludge bed area of 0.5 sq. ft. per capita was insufficient.

* Concluding chapter of the comprehensive report of the same title, as published in This Journal, 18, 5 (September, 1946).

Trickling filters operated at low rates, 30,000 persons per acre.

In World War II, the Office of Chief of Engineers on December 16, 1941, took over the Construction Division of the Office of the Quartermaster General, and was charged with the design of treatment works for the Army camps. Operation of plants was carried on through the Repairs and Utilities Division. The service commands were responsible for supervision of sewage works and post engineers were responsible for their operation. Analyses were carried on, in many cases by civilian chemists, under direction of the post engineer.

Sanitary Corps engineering officers were assigned to each service command, and in most cases to large camps, posts, stations and air fields, to assist in training sewage works operators, to make recommendations regarding operation, and to help interpret the results of laboratory analyses. This work was performed in conjunction with other duties in the field of environmental sanitation.

Design and Construction

Shortly after construction started, a report on bases of sewage treatment design was requested from the engineering firms of Greeley and Hansen and Metcalf and Eddy. This Engineering Board reported in December, 1940, on objectives, types of treatment and appropriate loadings of treatment devices.

In regard to types of treatment, the Engineering Board preferred sedimentation tanks with mechanical removal of sludge to Imhoff tanks, discouraged use of mechanical screens, preferred trickling filters to activated sludge plants because of relatively greater simplicity, and preferred high-rate filters to standard trickling filters because of the smaller amount of material required in their construction.

In June, 1941, the OCE Engineering Manual incorporated the suggestions made by the Engineering Board to the following extent:

"The degree of treatment required will depend upon the amount of diluting water in the receiving stream during periods of minimum flow, the condition of the stream as regards pollution, and the use of the stream below the proposed point of discharge. Consideration should also be given to local practice with regard to the degree of treatment being provided by existing plants, and the anticipated occupancy of the project." As to partial treatment, the manual states: "Where the effluent from the plant is to be discharged into a relatively large stream with a flow sufficient to provide a minimum dilution of about 4 cfs of stream flow per 1,000 population, sedimentation tanks with chlorination will usually be sufficient. Such partial degree of treatment may be suitable in cases where the effluent is to be discharged into tidal waters, or finally disposed by irrigation on land." For posts requiring additional treatment, the Manual states: "If a greater degree of treatment is required, consideration should be given to operating requirements, and the simplest type of plant should be used that will give the desired results. Where more than partial but less than complete treatment is required, single-stage high-capacity filters can be used to good advantage. Treatment by the activated sludge process, standard-rate trickling filters, or multi-stage high capacity filters will provide complete treatment where required."

The Manual also stated, "The use of high-rate filters . . . should be confined to localities where stone is not readily available or where space limitations and other factors require the use of such processes."

Some of the estimates of flow, char-

acteristics of sewage, load factors and bases of design given in the Engineering Manual, as revised in January, 1943, were as follows:

Average Flow (Airfields, Camps and Cantonments)

1. Permanent posts—100 g.c.d.
2. Mobilization type—70 g.c.d.
3. Theater of Operation type—50 g.c.d.

Average 16-hour flow taken as 125% of average 24-hour rate.

Maximum 4-hour average rate taken as 175% of average 24-hour rate.

Minimum 4-hour average rate taken as 40% of average 24-hour rate.

Extreme peak flows taken as 300% of average 24-hour rate.

Characteristics of Sewage

1. Suspended solids—0.27 lb./cap./day.
2. B.O.D. (5-day)—0.20 lb./cap./day.
3. Grease—0.09 lb./cap./day.

Design Capacity

1. Design capacity = authorized population × capacity factor.
2. Capacity factor table:

	Authorized Population	*Capacity Factor*
Less than	10,000	2.00
Less than	20,000	1.50
Less than	30,000	1.25
Less than	40,000	1.10
Greater than	50,000	1.00

3. Purpose of capacity factor—to provide for the following:

(a) Reasonable increases in population that may occur after construction.

(b) Variations in sewage flows and uncertainties as to actual sewage quantities.

(c) Unusual peak flows (to prevent extremely short detention periods in smaller units).

Hydraulic Design

1. Pipes, channels, hydraulic distributors, weirs, comminutors, and flumes designed for peak flows 300 per cent of 24-hour average flow.
2. Capacity of various units designed for 16-hour average flow rate equal to 125 per cent of 24-hour average flow rate.
3. Detention periods to be adequate for average 4-hour flows equal to 175 per cent of 24-hour average flow; however, in general, detention periods designed on 24-hour average flow.

Primary Sedimentation Tanks

Type of Treatment	*Detention Period (hours) Based on 24-Hour Average Flow*
Primary (no recirculation)	2.5
Standard trickling filter (including recirculation)	2.5
High-capacity filter (including recirculation)	2.5
Activated sludge (including recirculation)	1.5
Contact aeration (including recirculation)	2.5

Trickling Filters

In determining the amount of B.O.D. applied to filters, the amount of B.O.D. of the raw sewage is assumed to be reduced by 35 per cent in passage through primary sedimentation tanks.

1. Standard Trickling Filter (complete treatment), 600 lb. of applied B.O.D. per acre-ft. per day (for filters not greater than 6 ft. deep).
2. High-Capacity Trickling Filter (intermediate treatment), loading to depend upon degree of treatment selected, but not to exceed 3,000 lb. of applied B.O.D. per acre-ft. per day (for filters not greater than 6 ft. deep).

Final Sedimentation Tanks (required for trickling filter, activated sludge, and contact aeration processes)

1. Detention period (based on 24-hour average flow), 2.5 hours, including any recirculation of sewage or sludge.
2. Final tanks to have foregoing detention period in addition to any intermediate sedimentation between stages of biological treatment.
3. Depth of tank, 8 or 10 ft. Overflow rates less than 800 gal./day/sq. ft. of tank area (based on average daily rate).

Sludge Digestion Tanks

1. Capacities:

Type of Treatment	Capacity (cu./ft./cap.) Heated	Unheated
Primary	2.0	3.0
Standard Filter	3.0	4.5
High-Capacity Filter	3.0	4.5
Activated Sludge ...	4.0	6.0
Contact Aeration ...	3.0	4.5

Operation

In the initial phases of the program, operation was not all that could have been desired. Frequently no provision was made for operation until the cantonment had been completed. It was common procedure to assign operation of both water works and sewage treatment plants to the post detachment, which, more often than not, had no competent persons available. As a result, Architect-Engineers were themselves frequently obliged to devote a considerable amount of attention to plant operation and training of operators. In many cases strong representation was necessary in order to obtain competent operators.

Gradually, however, the personnel difficulties were resolved. An important factor in this connection was the program of operator instruction carried forward simultaneously in various service commands. In addition, state-sponsored short courses and "defense courses" were offered by a number of universities. Criticism of plant performance was greatly reduced as the effect of the educational program became manifest.

Limitations of the Survey

Insufficient data existed to permit an evaluation of the effect of the sewage plant effluent upon the receiving water. Although it was the general practice at military installations to perform periodically certain routine analyses upon samples from the receiving stream (DO, BOD, etc.), these were inadequate for the purpose of making a complete and integrated study. In particular, data regarding the amount of available dilution were found to be almost entirely lacking. Consequently the survey had to be limited to the problem of sewage *treatment* rather than the broader problem of sewage *disposal*.

Likewise it was found that it was not possible to make a detailed comparative study of costs of installation and operation. The difficulty stemmed in part from inadequacy of data. Available information relating to cost—such as power consumption, for example—pertained, in general, to overall power costs for the treatment plant and adjoining installations, including extraneous items as well as the unit or process in question. Moreover, it was considered that in view of the abnormal condition of the national economy during the period of construction, inclusion of costs was not advisable. Contracts for construction were drawn on a cost-plus-fixed-fee basis for all post units as a group. Cost data for individual units such as sewage plants could not be separated from overall post costs. Moreover, speed was essential; the gravity of the national situation made economy a secondary consideration. Cost data at hand appeared to be of little or no value to municipalities in a peacetime economy.

Total Sewage Plants

Table I, prepared by OCE, gives the total plants at Army posts in the U. S., some 399, and indicates their distribution as to type.

Classification of Survey Plants

For purposes of investigation, it was decided that two classifications of plants on the survey list of 133 would be used, as follows: (1) complete study, (2) partial study. Analysis would be concentrated upon the first "complete study" group. A basis of

TABLE I.—Types of Sewage Treatment Plants Installed at Army Posts in United States by Service Commands—1940 to 1945

Service Command	Primary Treatment			High Capacity Single Stage Filters			High Capacity Two Stage Filters			Standard Rate Filters			Intermittent Sand Filters			Activated Sludge		Contact Aeration			Totals
	No.	Sep. S.D.	Ox'n Pond	No.	Sep. S.D.	Ox'n Pond	No.	Sep. S.D.	Ox'n Pond	No.	Sep. S.D.	Ox'n Pond	No.	Sep. S.D.	Ox'n Pond	No.	Sep. S.D.	No.	Sep. S.D.	Ox'n Pond	
I	3/(3)	3	0	3/(3)	2	0	0	0	0	0	0	0	2/(2)	0	0	0	0	0	0	0	8
II	4	3	0	4	4	0	1	1	0	4/(2)	3	0	7/(4)	1	0	1	1	0	0	0	21
III	8/(3)	5	0	4	4	0	1	1	0	15/(7)	4	0	0	0	0	0	0	0	0	0	28
IV	17/(2)	14	0	12	12	0	1	1	0	28/(8)	21	0	10/(1)	3	0	9	9	5	5	0	83
V	1	1	0	1	1	0	1	1	0	14/(10)	9	0	2/(1)	0	0	2	2	0	0	0	22
VI	2/(2)	0	0	0	0	0	1	1	0	9/(2)	6	0	0	0	0	1	1	0	0	0	13
VII	7/(4)	3	2	3	3	0	4	4	0	24/(11)	13	0	2/(2)	0	1	0	0	6	6	0	46
VIII	10/(5)	4	0	7/(2)	5	1	5	4	0	27/(8)	18	1	4/(2)	1	0	3	3	30	30	3	86
IX	32/(20)	12	10	20/(7)	15	5	22/(4)	21	8	13/(11)	5	3	4/(4)	0	0	0	0	0	0	0	94
Totals	84/(39)	42	12	54/(12)	46	6	36/(4)	34	8	134/(59)	79	4	31/(16)	5	1	16	16	41	41	3	399/(130)*

Notes: (1)*This total represents number of plants analyzed to date and at least 80% of plants installed.
(2) Total number of plants with separate sludge digesters—268.
(3) Total number of plants with oxidation ponds—35.
(4) Six plants incorporate standard filters as additional units—1 in VII, 4 in VIII and 1 in IX Service Command; of these, 4 are for two stage high capacity filters and 2 for contact aeration plants.
(5) Three plants incorporate intermittent filters as additional units—1 each in I, VIII and IX Service Commands; 1 of these for single stage high capacity filters and 2 for standard filters.
(6) Two plants incorporate roughing filters as additional units in VIII Service Command—1 each for standard rate filter and activated sludge.
(7) One plant incorporates a high rate filter as additional unit in a contact aeration plant in VII Service Command.
(8) Numbers in parentheses indicate the number of plants included in the total which have Imhoff tanks.
(9) In some plants where Imhoff tanks are used, separate sludge digesters are also provided.
(10) Three chemical precipitation plants, one in VI and two in IX, were installed. These are not included in the table.
Sep.S.D. denotes Separate Sludge Digester.
Ox'n Pond denotes Oxidation Pond.

TABLE II.—Distribution of Plants in Complete Study Group

Group	Total No.	Location		Size		Loading		
		North	South	Large	Small	Under	Normal	Over
Primary settling	6	2	4	5	1	4	2	0
Filter Do-1	10	8	2	6	4	6	2	2
Filter Dr-1	6	2	4	3	3	4	1	1
Filter DR-1	5	1	4	4	1	2	3	0
Filter Sr-1	1	0	1	1	0	0	0	1
Filter SR-1	7	5	2	4	3	4	2	1
Two-stage filter	9	4	5	5	4	6	2	1
Contact aeration	5	0	5	1	4	1	1	2
Activated sludge	5	2	3	3	2	4	1	0
Oxidation pond	1	0	1	1	0	0	1	0
Total	56	24	32	33	23	32	16	8

D = Deep (over 4.5 ft.).
S = Shallow (under 4.5 ft.).
o = No Recirculation.
r = Low Recirculation Ratio (under 1).
R = High Recirculation Ratio (over 1).
1 = Single Stage.

selection for this group was evolved that consisted of minimum requirements as to sampling procedure, flow measurement, population data, and laboratory analyses. These criteria are outlined as follows:

A. Sampling—minimum requirement:

1. Period of compositing greater than 8 hours.
2. Samples composited proportional to flow (including recirculation) at intervals not greater than 2 hours.
3. Four composite samples per month.

B. Flow:

1. Meter and recorder or counter upon dosing tank.
2. Reasonably reliable quantitative information as to volume of recirculation.

C. Population: Data sufficiently detailed to permit evaluation of equivalent population.

D. Operating Data—minimum requirement:

1. Operational reports for more than an 8-month period.
2. Laboratory analyses to include both BOD and SS.

Table II gives a breakdown of the 56 complete study plants as to distribution, type and size.

Population Data

Population at a post was subdivided into four classifications for the purpose of investigation. These were: (1) resident military, (2) resident civilian, (3) non-resident military, and (4) non-resident civilian. Of these the first was invariably predominant. The number of civilian residents was usually negligibly small. Considerable difficulty was encountered in obtaining the number of non-resident military personnel; for the most part, available information represented estimates only. Non-resident civilian personnel included day workers, office workers, etc. From the numbers in each of the four classifications, an equivalent population for the post was computed. Equivalent population was defined as the resident plus one-third of the non-resident population.

CHARACTERISTICS OF MILITARY SEWAGE

Environmental conditions at military establishments led to the production of sewage that differed significantly from municipal sewage in a number of respects. The chief differences were that the sewage (a) tended to be more concentrated; (b) had a greater proportion of volatile matter relative to the total solids; (c) contained a higher proportion of grease; and (d) exhibited larger and more rapid variations in diurnal flow.

With minor exceptions, there were no industrial wastes in the sewage nor extraneous matter that interfered with treatment; sewage in military installations was essentially of a domestic character. Separate sewer systems were the rule.

The differences between military and municipal sewage stemmed primarily from the military regime, which prescribed a systematized pattern of sleeping, working and eating.

Flow Measurement

Venturi meters were not widely used in sewage plant flow measurement, although they gave satisfactory service particularly when installed in plant effluent lines.

The Kennison nozzle, while not used in a large number of plants, proved to have decided advantages. Its space requirements are modest and the fact that it may be attached to the end of a pipe or conduit made installation possible at a number of locations not originally equipped for flow measurement.

Of 126 plants for which flow measurement data were investigated, 72 had Parshall flumes and the remaining 54 were equipped with rectangular flumes and weirs. Of the 56 plants in the complete study group 39 were equipped with Parshall flumes.

Hourly Flow Variation: Each plant in the survey list that was equipped with flow recording apparatus submitted a typical chart indicating variations in flow throughout the day.

Of the types of hourly flow distribution, the following were the most common:

(1) Monomodal (Figure 1, General Hospital)
(2) Bimodal:
    (a) With evening maximum predominant (Figure 2)
    (b) With morning maximum predominant (Figure 3)
(3) Trimodal (Figure 4).

Flow Due to Laundry Waste: Despite the fact that laundry waste constituted a relatively low proportion of the overall volume treated, it sometimes occasioned operating difficulties by interfering with biochemical processes. This was to be attributed largely to the fact that laundry waste was often discharged in "slugs" at times when treatment units were already carrying peak loads. The problem was rendered more difficult at a number of posts at which laundry work was done for several nearby installations.

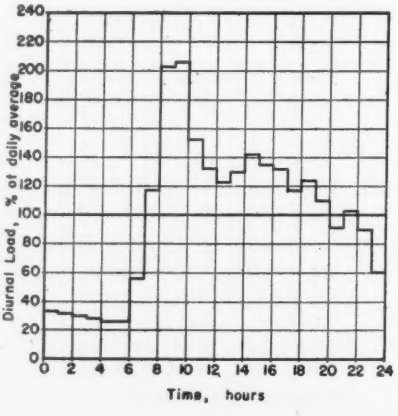


FIGURE 1.—Typical hourly flow variation. Composite graph of Bushnell, Darnall and Fitzsimons General Hospitals.

An approximate figure on volume of waste appears to have been 5 gal. per pound of clothes laundered. In warm months about 1.2 lb. of clothes per capita were washed daily; in winter the amount dropped to about 0.6 lb.

In general, laundry waste constituted more of a problem in the smaller installations. By January 1943, however, many of the more flagrant instances of interference with sewage treatment had been ameliorated. In a number of cases adjustments were made in laundry practice; in others, holding tanks were provided in order to obtain a more uniform distribution of flow to the plant.

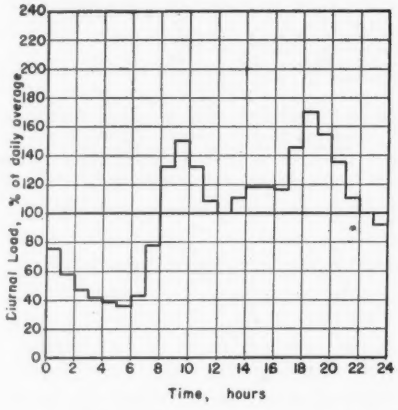


FIGURE 2.—Typical hourly flow variation. Composite graph of Fort Dix and Camp Reynolds.

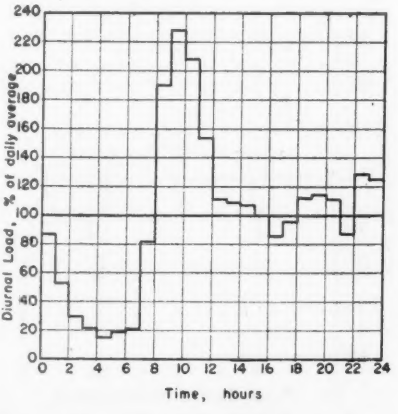


FIGURE 3.—Typical Hourly Flow Variation at Camp Myles Standish.

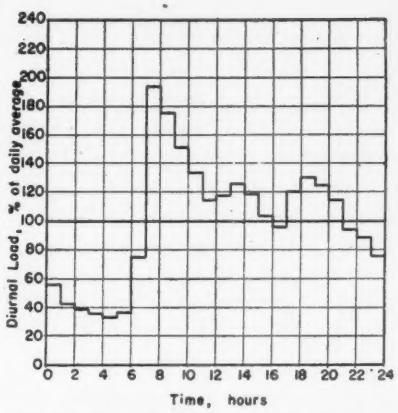


FIGURE 4.—Typical hourly flow variation. Composite graph of Fort Huachuca No. 1, Fort Huachuca No. 2 and Camp Edwards.

Characteristics of Sewer System Affecting Flow

The length and slope of the sewers carrying sewage to a plant determine to a certain extent the variation of flow. The action of the sewer system is particularly important with respect to fluctuations of duration of the order of one hour. The extent to which minor discontinuities in flow entering the system are damped out in passage depends primarily upon the length and the time of travel. A parameter providing an approximate measure of the influence of sewers is "lineal feet of sewers per m.g.d. (average daily flow)." This quantity is roughly proportional to the detention period in sewers, and reflects the damping action.

It is to be emphasized that the parameter, lineal feet per m.g.d. of flow, does not reflect the size of the installation. Very little correlation was exhibited between the size of post

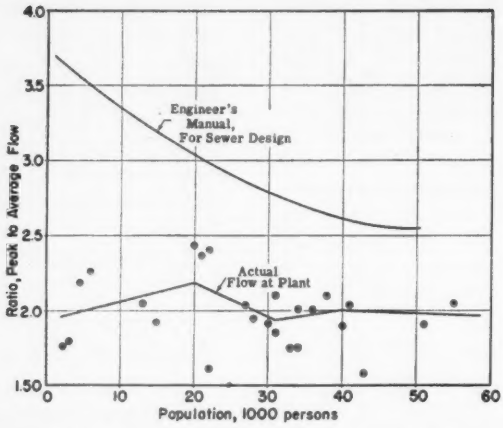


FIGURE 5.—Relation between post population and variation of flow. Data for lower curve are taken from twenty-five typical posts based on flow at plant. Curve is drawn through group medians. Data for upper curve are taken from OCE Engineering Manual, for sewer design. Difference between curves reflects in part the dampening effect of sewerage system.

and flow fluctuations. Figure 5, with data from 25 posts, shows a nearly constant average ratio of peak to average flow of about 2.0 for a population range of about 30 to 1. On Figure 5, as a matter of reference, is included the relationship between peak flow and population that is specified for sewer design in the Engineering Manual. In view of the damping effect of sewers, it is to be expected that higher peak flows will occur in upstream portions of sewer systems than at sewage treatment plants. The difference in the two curves of Figure 5 reflects the influence of the sewer system and, in part, a factor of safety that is customary in conservative hydraulic practice.

The reversal of direction in the lower curve does not imply a significant trend in the points; it denotes merely sampling fluctuations characteristic of limited data.

Daily Flow Variation

Having considered the diurnal distribution of flow, it is pertinent to take up the matter of variation in flow from day to day throughout the week and month.

At Fort Jackson (Figure 6) Sunday minima were pronounced, particularly during the summer months, amounting to about 80 per cent of the monthly average flow. Maxima occurred usually on Mondays and Fridays. In addition to the marked weekly fluctuation in population at

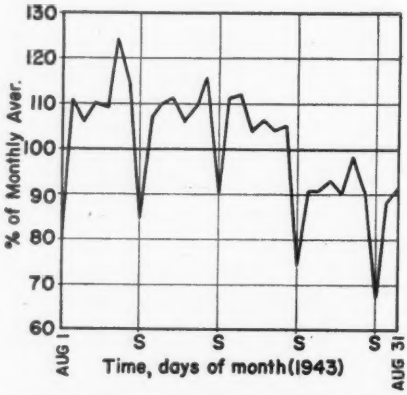


FIGURE 6.—Variation in sewage flow during August, 1943, at Fort Jackson.

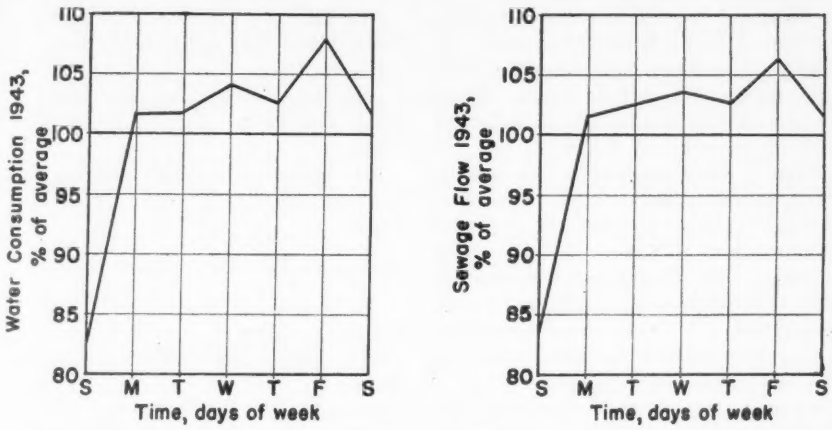


FIGURE 7.—Variation in water and sewage flow during week at Camp Edwards. Curves represent average daily values for 1943.

Fort Jackson during August, 1943, a downward trend indicating troop movement is evident throughout the month. Trends upward and downward were common in posts surveyed.

Figure 7 indicates the variation in water and sewage flow during the week at Camp Edwards, as based upon a 12-month record. The two distributions are quite similar, with Friday and Sunday representing the maximum and minimum days.

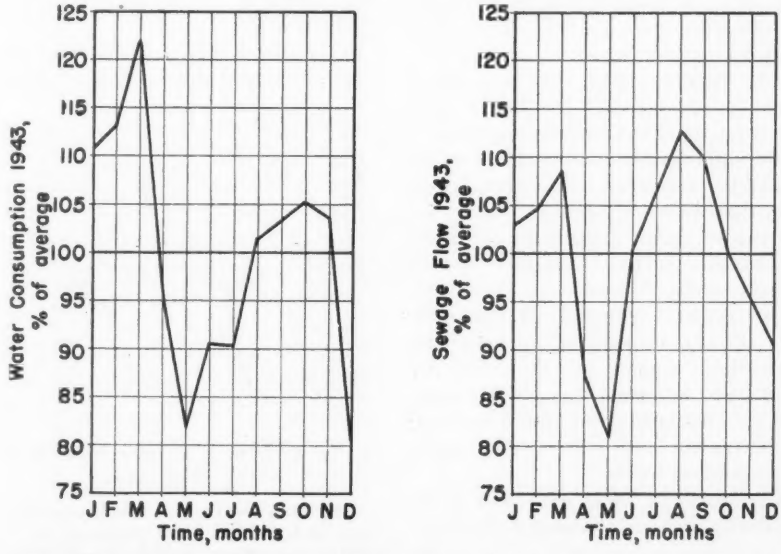


FIGURE 8.—Variation in water and sewage flow during 1943 at Camp Edwards. Total sewage flow during year was 86 percent of total water consumption.

Figure 8 represents the distribution of flow at Camp Edwards over the entire year, as based upon monthly average water and sewage flows. These curves display a number of points of difference, chief of which is the discrepancy between water and sewage flow during March, 1943. The total sewage volume throughout the year amounted to 86 per cent of the water volume. The 14 per cent difference in the two volumes was sufficient to account for the fairly large temporary disparities noted from time to time between sewage and water flow. Changes in training schedules, bivouacking, and sewer flushing, which were all more or less intermittent operations, affected the proportion of water entering sanitary sewers.

BOD and SS in Raw Sewage

The overall weighted average BOD for 44 plants was 0.192 lb. per capita, and the suspended solids value was 0.154 lb. per capita. The value for BOD is in excellent agreement with the expected value of 0.20 given by the Engineering Manual. The value of 0.154 for SS, however, was considerably smaller than the anticipated value of 0.27 given in the Manual and in the report of the Engineering Board. It is significantly lower than values normally occurring in comparable municipalities. A median value for 23 towns and cities with sanitary sewers, as reported by Keefer, is 0.18 lb. per capita.

One might have expected that military sewage, because of its high concentration, would be high in per capita SS, but such was not the case, and no correlation was found between concentration and pounds per capita of suspended solids.

Variations in BOD and SS may be attributed to the following factors:

(1) Training schedules that involved bivouacking to a significant degree.

(2) Laundry wastes, particularly at installations that did laundry work for adjacent posts.

(3) Imperfections inherent in evaluating population, flow, and concentration.

(4) Differences in efficiency of grease recovery and trap maintenance programs.

Sewage Volume Per Capita

In 48 plants, the average volume of sewage amounted to 74.7 gal. per capita daily. This value was in reasonable agreement with an anticipated amount of 70 g.c.d. stated in the Engineering Manual for airfields, camps, cantonments and troop facilities of the mobilization type. Earlier in the program, however, per capita flow was significantly higher than 70 g.c.d. in many plants.

Hourly Variation in Composition of Raw Sewage

Figure 9 indicates hourly distribution of flow and BOD for representative ground force installations of medium size.

This graph displays in a striking way the rapid increase in flow and

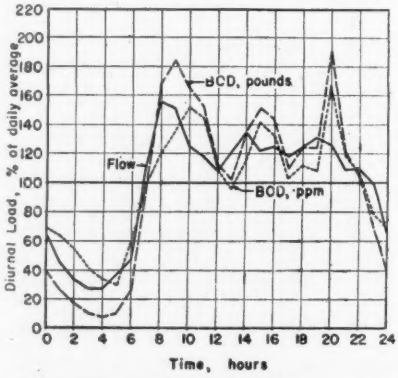


FIGURE 9.—Typical hourly variation in flow and BOD. Data represent average rate for each hour. Composite—Fort Leonard Wood, Camp Campbell, Camp Roberts and Camp Swift.

BOD during the morning. In all posts the distribution curve of BOD in pounds was observed to "outswing" that of the flow. The bulk of the organic load was delivered in a significantly shorter time than was the peak volumetric load. The maximum 1-hr. average flow varies from 144 per cent of the daily average flow in the large posts to 189 per cent in small air force installations. Similar trends may be noted in the maximum 4-hr. and 16-hr. flows, and in the minimum 4-hr. flow. The small plants experienced a markedly greater concentration of diurnal load. In the following compilation, results are compared with design expectation as set forth in the Engineering Manual.

	Flow—Per Cent of Average Daily Flow			
	Max. 1-hr.	Max. 4-hr.	Max. 16-hr.	Min. 4-hr.
Large posts	144	140	120	43
Medial posts	163	146	127	28
Small posts (airfields)	189	148	126	38
General hospital	227	174	137	13
Engineering Manual	—	175	125	40

With respect to the maximum 4-hr. flow, the design figure of 175 per cent is seen to have been somewhat conservative. In a number of plants, however, the hourly flow distributions during a substantial proportion of days were so non-uniform as to closely approach the design criterion for maximum 4-hr. flow. This criterion, it should be observed, was conceived primarily as a guide for designing units in which adequate detention period was essential. The maximum 16-hr. flows experienced were about in line with design expectation. Minimum 4-hr. average flows in many posts, however, fell below 40 per cent of the daily average. In a number of plants, anaerobic conditions in settling tanks developed as a result of low night flow and, because of effects concomitant with septicity, remedial measures had to be taken.

The characteristic rapid rate of flow increase in the morning may be quantitatively stated in terms of the maximum hourly rate of increase of flow (g.c.d.). With a daily average of 70 g.c.d., the following flow accelerations were typical:

	Hourly Rate of Increase in Flow (g.c.d./hr.)
Large posts	45
Medial posts	50
Small posts (airfields)	77
General hospital	78

The increase in flow during the early morning hours was so rapid that a series of traveling waves was created in the sewer system. Wave velocities in general exceeded the mean velocity of flow; consequently a flow increase at the plant was experienced before the first significant increase in organic load became manifest. The first part of the new flow was relatively weak sewage and a significant BOD increase lagged about an hour behind the flow increase.

Equivalent Population

The proportion of the total load arriving at plants between 10 A.M. and 6 P.M. provided a basis for estimating the sewage contribution of non-resident population. Results giving factors for estimation of equivalent population are indicated in the following compilation:

Size of Post	Factor	
	For Flow	For BOD
Greater than 15,000	8/24	9/24
5,000 to 15,000	9/24	9/24
Less than 5,000	10/24	12/24
Average	9/24	10/24

Influence of Length of Sampling Period

Analysis of the flow and organic load distribution for 17 plants yielded the following average results for raw sewage BOD (weight) when sampling periods were short:

Sampling Period	Duration (hr.)	Per Cent of 24-hr. Average Weight of BOD
8:00 A.M. to 4:00 P.M.	8	144
8:00 A.M. to 8:00 P.M.	12	140
8:00 A.M. to 12:00 P.M.	16	135
8:00 A.M. to 8:00 A.M.	24	100

Sampling by equal portions results in BOD concentration that averages about 11 per cent too low. Such an undervaluation is a consequence of including a disproportionately large amount of weak night sewage that dilutes the composite too much.

It is evident that short sampling periods have the effect of exaggerating plant performance, not only from over-estimation of raw sewage strength, but also from under-estimation of final effluent concentration.

Grease in Raw Sewage

Results of grease analyses in raw sewage at seven representative plants indicated that the concentration of ether soluble matter varied from 33 to 255 p.p.m.—a variation of almost 8 to 1. Average concentration for the seven plants was 164 p.p.m., and the median, 151 p.p.m. On a per capita basis, values ranged from 0.043 to 0.139 lb. daily; the mean value was 0.08 lb. per cap. per day. This value is in excellent agreement with the value of 0.09 lb. per cap. per day of ether soluble material used as a design criterion.

Variations in amounts of grease in sewage at different posts were substantial, reflecting differences in efficacy of grease recovery programs and trap maintenance. Grease retention characteristics of sewer systems also were a factor; grease adhering to sewer walls would, at some posts, slough off at irregular intervals and enter treatment units in "slugs."

Excessive amounts of grease in raw sewage caused operating difficulties at a number of plants, particularly in the early part of the war. Tests by the Water and Sewer Unit of the Repairs and Utilities Branch, indicated that grease traps outside mess halls, which were designed by the Engineering Branch and R. & U., were not satisfactory. In addition, it was found that they were not cleaned properly and were in general insanitary. Cast-iron traps in kitchen sinks had unsatisfactory hydraulic characteristics; they accumulated grease and discharged it in a concentrated load to the sewer. High peak discharges from sinks were reduced by installation of cast-iron clean-out control type tees (one per sink) at the end of the drain pipes. This appurtenance successfully ironed out flow fluctuations, yet still permitted of reasonable times of discharge.

A number of reasons are advanced to explain the high grease contents so characteristic of military sewage. In part, the large amounts of grease may be attributed to consumption of more meat by a male population in a physically rigorous mode of life. Many fried foods were eaten; a fryer was standard equipment in each kitchen. These circumstances were conducive to high grease concentration in dishwater. Another factor was the use of a considerable quantity of soap per capita.

Part of the grease came from airplane and auto service shops. Washing and cleaning activities, particularly with gasoline, resulted in the carrying of grease and oil into sewage. At a number of posts wash racks had to be disconnected from the sanitary sewer system.

TABLE III.—Characteristics of Raw Sewage at Sheppard Field, Texas

Date	Day	BOD (p.p.m.)	Total SS (p.p.m.)	Fixed SS (p.p.m.)	Total Solids (p.p.m.)	Fixed Solids (p.p.m.)	Dissolved Solids* (p.p.m.)	Oxygen Consumed (p.p.m.)	NH_3-N (p.p.m.)	Alkalinity (p.p.m. as $CaCO_3$)	pH	Chlorides (p.p.m.)	Population	Av. Flow (m.g.d.)
1/26/43	Tue	422	504	116	1,488	666	984	168	45	375	8.2	310	31,347	1.30
1/27/43	Wed	520	356	—	1,368	736	1,012	285	50	350	8.1	455	32,086	1.33
1/28/43	Thur	397	—	—	1,568	796	1,264	220	56	340	8.5	450	32,685	1.35
1/29/43	Fri	522	304	20	1,524	612	1,220	215	32	310	8.1	450	33,127	1.41
1/30/43	Sat	439	384	60	1,540	688	1,156	310	—	370	8.3	390	37,711	1.35
1/31/42	Sun	539	352	48	1,572	796	1,220	260	46	380	8.2	370	35,016	1.21
2/1/43	Mon	403	380	48	1,416	804	1,036	290	58	360	8.2	330	36,392	1.38
2/2/43	Tue	562	384	56	1,732	1,036	1,348	340	52	310	8.0	360	36,837	1.38
Average		476	380	60	1,526	767	1,152	274	48	350	8.2	389	34,400	1.34

* Calculated from total solids and suspended solids.

Establishment of the grease recovery program by the Salvage Branch of the Office of the Quartermaster General was a significant factor in the eventual reduction of grease content of sewage at many posts. The Salvage Branch collected approximately six million pounds of grease each month. This included interceptor grease as well as frying fats and other kitchen wastes.

Composition of Military Sewage

An investigation of characteristics of raw sewage at Sheppard Field, Texas, by Cox and Fix gave results as presented in Table III. Each of the figures represents the result obtained from a 24-hr. composite sample made up of increments proportioned according to flow and stored in a refrigerator.

TABLE IV.—BOD Characteristics of Raw Sewage. Parameters of Unimolecular Equation Fitted to Data

Post	SS (p.p.m.)	1-Day BOD (a) (p.p.m.)	5-Day BOD (a) (p.p.m.)	Ultimate First Stage BOD, L (p.p.m.)	Reaction Velocity Constant, k, per day
Buckley Field	311	93	256	303	0.16
Camp Claiborne No. 1	210	122	230	243	0.30
Camp Crowder	—	127	358	437	0.15
Enid AAF	319	205	530	605	0.18
Fitzsimons Gen. Hosp.	—	157	485	647	0.12
Camp Hood	436	235	620	721	0.17
Lockbourne AAF	—	80	185	205	0.21
Fort Logan	210	124	328	381	0.17
Fort George G. Meade	558	207	618	798	0.13
Camp Joseph T. Robinson	238	281	648	704	0.22
Will Rogers Field	280	84	189	204	0.23
Fort Sill	331	117	268	292	0.22
Sioux Falls	732	216	555	635	0.18
Camp Swift	602	280	680	755	0.20
Waco AAF	187	103	287	351	0.15
Fort Francis E. Warren	726	205	677	997	0.10

(a) Based on theoretical curve.

Low per capita flows at Sheppard Field were the result of the water conservation program, replacement of automatic flush valves with manual flush valves on urinals, and water discipline training by the Army.

BOD Characteristics of Raw Sewage

In Table IV are shown results indicating the cumulative biochemical oxygen demand exerted by raw sewage grab samples at various plants. The curves represent the unimolecular equation for the first stage of biochemical oxidation. The data are analyzed in Table IV in which parameters of the unimolecular equation,

$$y = L\ (1 - 10^{-kt})$$

are shown. The values of L, representing the ultimate first-stage demand, vary from 204 to 997 p.p.m. with an average of 517 p.p.m. The average 5-day BOD is 432 p.p.m. which amounts to 84 per cent of the ultimate L. The average value of the one-day BOD is 165, which is 32 per cent of the ultimate L.

The commonly accepted value of the reaction velocity constant k, for municipal sewage, is 0.10 per day. The average k value observed at the 16 military posts of Table IV was 0.18 per day. The implication is that military sewage is more rapidly oxidized than municipal sewage. Quantitatively the difference is shown in the following table:

	Per Cent of Completion of Ultimate		
	First-Stage BOD		Ultimate
	In 1 day	In 5 days	
With $k = 0.10$	20.5	68.0	100
With $k = 0.18$	34.0	87.4	100

Precision of the Five-Day BOD Determination

In addition to the question of the interpretative value of the BOD determination as a measure of sewage putrescibility, another problem of practical importance emerges—the reproducibility of the BOD test. Errors in measurement of concentration inevitably have an obscuring influence upon evaluation of plant and unit performance. Errors in measurement of concentration may be attributed to: (a) improper methods of collection; (b) errors made in the laboratory; (c) fluctuations inherent in samples of a non-homogeneous fluid. In order to ascertain the magnitude of the combined effects of these factors, a special study was conducted in the Eighth Service Command under the direction of Major R. M. Dixon.

Results submitted by eleven plants (Table V) indicated that the average value of the coefficient of variation was 7.45 per cent. The magnitude of the range relative to the standard deviation was about 3.2, suggesting that the dispersion of individual BOD values about the mean of each set was approximately in accordance with the normal curve of error. Thus the following interpretation may be made, that two-thirds of the BOD determinations, on the average, may be expected to fall within about 7.5 per cent of the correct value.

Condition of Sewage

Military sewage normally arrived at treatment plants in a fresh and uncomminuted condition. Odor generally was slight. Color was fairly light, and black constituents indicative of the formation of sulphides were not usually present. Oxygen content in raw sewage normally was low and usually zero during moderate and peak flow periods, except at plants where surface water entered the sewers.

TABLE V.—Precision of 5-Day BOD Determinations, Military Sewage Treatment Plants. Single Dilution, Nine Bottles

Name	Flow (m.g.d.)	Dilution (%)	BOD (p.p.m.)			S (a)	C_v (b)	(Max.-Min.) ÷ S
			Mean	Max.	Min.			
Camp Hood (North)	2.75	1	353	373	338	13.53	0.0384	2.59
	2.85	1	369	385	360	8.03	0.0218	3.11
Enid AAF	—	0.67	367	420	300	41.85	0.114	2.87
	—	0.67	335	495	195	79.37	0.2369	3.78
Will Rogers Field	—	1	272	310	210	29.06	0.1068	3.44
	—	1	366	540	210	108.86	0.2974	3.03
Fort Sill	2.90	1	422	445	400	12.28	0.0291	3.66
	2.60	1	439	495	410	31.10	0.0709	2.73
South Camp Polk	1.30	1.5	367	413	320	25.52	0.0695	3.65
	1.50	1.4	388	393	371	7.29	0.0188	3.02
Camp J. T. Robinson	—	0.73	472	510	430	28.63	0.0607	2.79
	—	0.73	582	630	550	24.01	0.0413	3.33
Camp Swift	—	1	373	440	340	30.01	0.0804	3.33
	—	1	240	250	230	6.46	0.0269	3.10
Camp Claiborne No. 1	—	1	207	220	180	14.15	0.0684	2.83
	—	1	227	240	200	17.32	0.0763	2.33
Camp Fannin	1.50	1	533	580	490	26.46	0.0496	3.41
	1.00	1	585	625	559	24.01	0.0410	3.12
Lake Charles AAF	—	1	234	252	222	5.41	0.0231	5.55
	—	1	336	362	312	15.09	0.0449	3.32
Camp Plauche NOPOE	—	—	436	470	400	28.48	0.0653	2.46
	—	—	324	350	300	18.79	0.0580	2.66
Average	—	—	—	—	—	27.08	0.0745	3.19

(a) S = Standard Deviation.
(b) C_v = Coefficient of Variation = Standard Deviation ÷ Mean.

SCREENS, RACKS, COMMINUTORS AND GRIT CHAMBERS

Screening

Design and operation of screens at military sewage plants differed little from corresponding practice at municipal plants. All plants investigated were equipped with either coarse screens or comminutors. A common installation was the use of inclined racks in parallel with a comminutor; racks were used when comminutors were out of service for purposes of inspection and repair.

Screens and racks were generally inclined 45 degrees with the horizontal. Bar openings varied from ¾ to 1¾ in. with the average somewhat over an inch. Clear openings between bars averaged about 75 per cent of the width of channel. Nearly all screens were hand-cleaned; only a few mechanical screen installations were made. The average amount of screenings in 18 plants was 3.2 cu. ft. per m.g. of sewage with a range of 0.8 to 9.0 cu. ft. per m.g. This constituted a significantly greater amount of screenings than is usual at municipal plants utilizing racks of comparable size. For example, 29 plants with screens with 1- to 1⅝- in. openings, according to Keefer, gave a median removal of 1.6 cu. ft. per m.g. The difference is to be attributed primarily to freshness of military sewage.

Comminutors

A high proportion of plants were equipped with comminutors. The satisfaction of the operator with this equipment was nearly universal. In view of the heterogeneous condition of the raw sewage, the comminutor performed an especially valuable service at military installations. Maintenance problems were relatively minor; only in a few instances were difficulties encountered. Excessive rates of teeth abrasion were, in a number of instances, lessened by installation of grit chambers.

Claims as to the effectiveness of the comminutor that appear to have been corroborated by field survey and reports of over a hundred operators are as follows: (1) the labor of cleaning, transporting and burying screenings was eliminated; (2) odor problems associated with screenings were obviated; (3) clogging of piping, check valves and pumps by primary sludge was substantially reduced; and (4) pulsating flow through primary settling tanks with concomitant impairment of settling efficiency due to intermittent build-up and release of head between screen-cleanings, was done away with by the comminutor.

Grit Chambers

At a number of posts, grit chambers were installed after the treatment plant had been in operation. Much benefit was derived from grit chambers at those cantonments using old sewers from World War I days. Such old sewers often had to be practically reconstructed. It was frequently discovered that large quantities of grit had entered the system prior to reconstruction, presumably through manholes originally equipped with wooden covers of 1917 construction.

In the newly constructed posts with separate sewers, grit chambers were generally not installed and in most instances results justified the omission. However, some plants, especially those located on sandy soil, experienced difficulty with grit. One troublesome source of grit was ashes entering through floor drains in kitchens. In other plants poor sewer construction, stemming in part from the urgency and haste of the building program, resulted in much grit being in the system at the time of acceptance.

Rock disintegration in filters intro-

duced formidable operating problems at certain posts, particularly on the West Coast. At one plant where deep grit chambers had been installed between the filters and secondary settling tanks, rock debris had to be cleaned out every month.

The rectangular grit chamber with velocity of about 1 f.p.s., was the design generally favored. Sutro weirs, Parshall and Palmer-Bowlus flumes were employed for velocity control. Grit generally contained a substantial amount of organic matter and burial was a common method of disposal. The average amount of grit was 2.1 cu. ft. per m.g. The median amount of grit collected at 40 municipal plants as reported by Keefer was 3.0 cu. ft. per m.g. At military posts, the average number of days between cleaning was five.

SEDIMENTATION

Both rectangular and circular settling tanks were used, but no data are available to indicate the relative merits of each type. Detention periods varied over a wide range, mostly in the bracket from 2 to 4 hours. Some 18 installations were studied, as shown in results in Tables VI and VII.

BOD and suspended solids reductions are plotted in Figure 10.

Comparison of Sedimentation Performance with Municipal Plants

Despite the circumstance that detention periods in military sewage plants were longer than those usual in municipal practice, performance as measured by removal of BOD was distinctly inferior. Keefer reported results for 26 municipal plants in which the average removal of BOD in pri-

TABLE VI.—Operation of Settling Tanks

Post	Schedule Sludge Removal—No. per day	Detention Period (hr.)			Surface Settling Rate (g.p.d./s.f.)		
		At Av. Flow	At Max. Flow	At Min. Flow	At Av. Flow	At Max. Flow	At Min. Flow
Blanding	8	4.65	1.81	27.20	435	1,125	75
Davisville	3	2.26	1.69	3.10	638	850	465
Funston	9	5.38	2.16	—	317	791	—
S. Johnson Field	6	3.96	2.15	10.30	444	817	170
Peary	3	3.45	2.92	4.08	522	615	442
Wheeler	8	2.92	1.26	6.80	678	1,570	292
Campbell	3	4.08	2.39	16.10	408	694	103
Crowder	6	4.42	2.03	19.70	418	912	94
Fitzsimons G. H.	—	3.92	1.68	18.40	459	1,072	98
Gordon	—	4.22	1.91	16.20	429	946	112
Callan	6	1.51	1.06	2.26	1,430	2,040	957
Drew Field	2	2.59	1.52	6.67	693	1,184	270
Knox	4	2.20	1.40	3.12	648	1,050	462
Bragg	2	2.87	2.31	3.81	627	782	473
Callan	cont.	1.38	0.98	2.06	1,450	2.040	970
Claiborne No. 1	—	0.15	0.094	0.33	9,600	15,300	4,370
Drew	cont.	1.67	1.15	2.76	1,080	1,570	652
Bragg	cont.	2.61	2.14	3.36	690	842	537

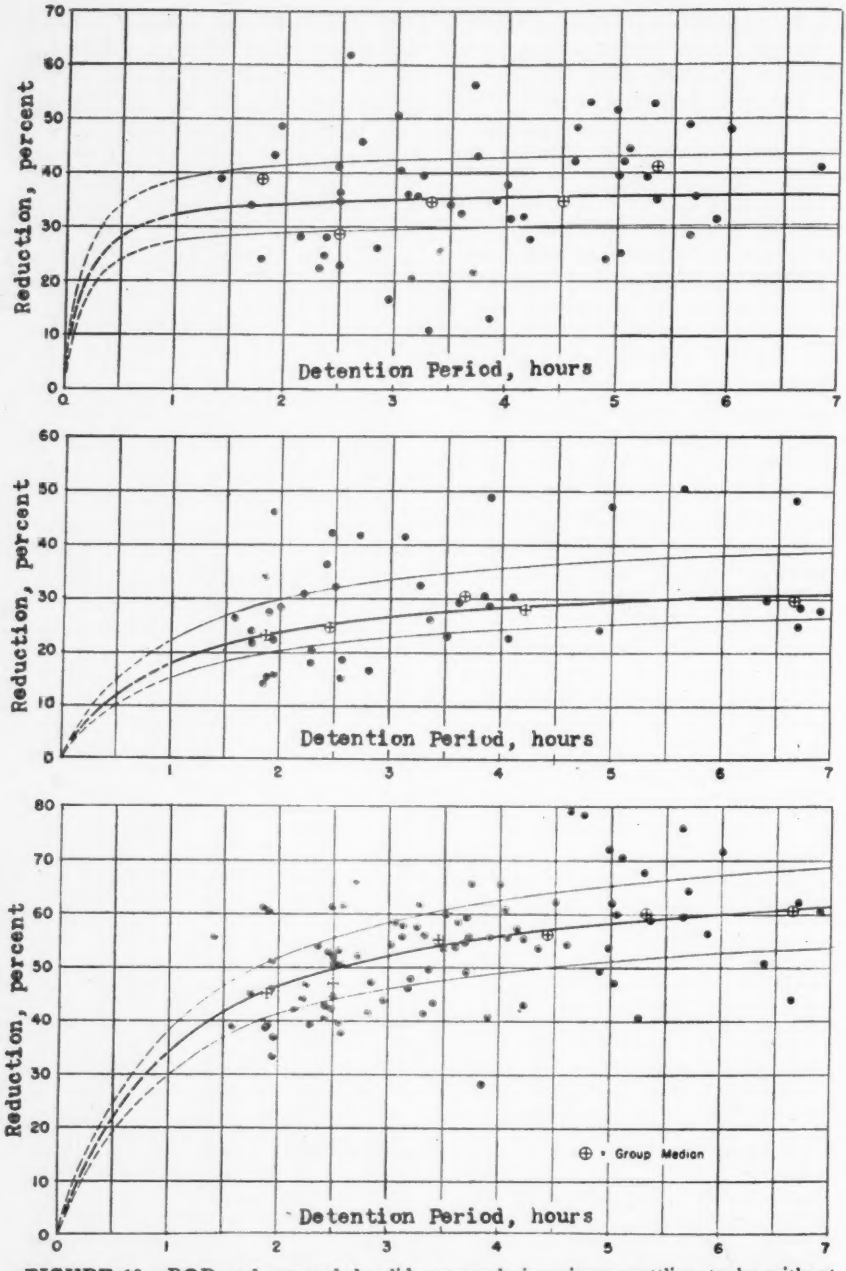


FIGURE 10.—BOD and suspended solids removals in primary settling tanks without recirculation. Top—BOD reduction from sewage containing over 350 p.p.m. Center—BOD reduction from sewage containing less than 350 p.p.m. Bottom—suspended solids reduction.

TABLE VII.—Loading and Performance of Settling Tanks

Post	Tank Influent				Tank Effluent		Reduction (%)		Sludge Removed	
	Total (m.g.d.)	Recir. Ratio	BOD (p.p.m.)	SS (p.p.m.)	BOD (p.p.m.)	SS (p.p.m.)	BOD	SS	Gal. per M.G. Sewage	Vola. Sol. (% of Tot. Sol.)
Blanding	1.820	0	195	311	141	125	27.3	60.0	4,100	81.0
Davisville	1.100	0	207	271	153	155	26.0	43.0	7,460	74.7
Funston	0.520	0	291	335	156	148	46.4	55.7	7,980	64.8
S. Johnson Field	1.220	0	349	279	207	152	40.6	45.5	17,700	75.0
Peary	3.960	0	363	291	144	128	60.4	56.2	—	—
Wheeler	1.600	0	391	270	259	115	33.8	57.2	7,180	76.1
Campbell	1.940	0	53	75	22	27	59.4	64.0	—	—
Crowder	2.000	0	44	90	29	32	33.0	64.5	—	—
Fitzsimons G. H.	0.440	0	118	87	68	37	42.7	57.6	—	—
Gordon	1.760	0	108	86	70	34	35.6	60.9	—	—
Callan	1.390	0.85	235	240	197	217	16.1	9.5	10,250	78.3
Drew Field	1.570	0.16	265	266	132	117	50.2	56.9	6,870	66.4
Knox	5.660	0.77	217	208	134	107	38.2	48.3	6,760	69.9
Bragg	10.740	1.93	169	126	147	87	13.0	31.0	8,440	79.4
Callan	1.390	0.85	118	278	77	83	34.7	70.2	—	—
Claiborne No. 1	2.650	0.24	—	—	71	74	—	—	—	—
Drew Field	2.650	0.79	48	63	34	35	29.2	44.6	—	—
Bragg	11.820	2.21	70	62	61	45	12.8	27.4	—	—

mary settling tanks was 35.1 per cent. In these plants the average strength of raw sewage (BOD) was 234 p.p.m. However, in military plants with raw sewage less than 350 p.p.m. BOD, the median removal was only 28.5 per cent. In municipal plants with raw BOD in excess of 300 p.p.m. removals of BOD of 40 per cent are normal; such performance excels that noted in military plants treating concentrated sewage.

In seeking a reason for the disparity as to settling performance between military and municipal installations, the hypothesis that detention periods in the former were *too long* must be rejected.

It is believed that one factor, more than any other, was responsible for differences in settling efficiency observed between military and civilian plants. This was non-uniformity of flow. Flow at military installations, as has been stated, tended to be less uniform than that in municipalities of corresponding size as a result of the following two factors: (1) regimented mode of life at cantonments inherent in military training; and (2) improper pump sizes and float switch adjustments at many posts that were conducive to pulsating flow.

TRICKLING FILTERS

Selection of Plants

More than one-half of all sewage treatment plants installed at military posts during World War II included trickling filters. From an approximate total of about 300 filter plants, 34 were selected for complete study. It is pertinent to note that the selec-

tion of filter plants was based upon completeness and reliability of design and operational data; it was not based upon performance. The attempt was to emphasize normal rather than exceptional experience. Consequently, the results depict what actually occurred in filter plants as a group, without special emphasis upon a few plants that happened to operate under unusually propitious circumstances conducive to outstanding results. With every type of trickling filter installed there were instances of notable performance as well as of substandard performance.

Arrangement of Filters in Groups

Three attributes of design and operation of filters provided a logical basis of classification which is outlined as follows:

(a) As to depth—deep or shallow. Average depth of media greater or less than 4.5 ft.

(b) As to amount of recirculation. Recirculation ratio through filter greater or less than 100 per cent.

(c) As to number of stages—single- or multi-stage. Operation of filters in series.

On the basis of this method of grouping, the 34 plants are subdivided into the various categories. The number of plants in each division is indicated in the following:

Division I: Deep filters without recirculation—10 plants.

Division II: Deep filters with recirculation—11 plants.

(a) Low recirculation ratio—6 plants.

(b) High recirculation ratio—5 plants.

Division III: Shallow filters with recirculation—8 plants.

(a) Low recirculation ratio—1 plant.

(b) High recirculation ratio—7 plants.

Measures of Loading and Performance

Two methods of expressing performance were found to be useful. *Per cent efficiency* of a unit was based upon the total load applied to a unit irrespective of reduction effected by other types of plant units. *Per cent removal* of a unit was defined as the percentage of the total plant load removed by that unit.

When flow is recirculated through primary settling tanks, it becomes impossible to assess accurately that proportion of the BOD (or SS) removed in the primary settling tank coming from the raw sewage as distinct from the recirculated flow. Hence an assumption is necessary in order to estimate the load of raw settled sewage applied to secondary biological units. In calculation of the load applied to these units it was assumed that the *per cent* of BOD (and SS) removed from the recirculated flow by the primary settling tank was the same as that observed to be removed in the final settling tank.

Deep Filters Without Recirculation

In Table VIII is presented a summary of the operation and performance of ten filter plants that did not employ recirculation. Two posts, Camp Swift and Turner AAF, were in the South; the others were located in middle latitudes of the nation. Nine plants were at army posts; one was at a naval installation, the Great Lakes Naval Training Center. The period of operation investigated at each plant varied from 12 to 20 months. All but two of the plants (Great Lakes and Lockbourne) may be considered as standard rate plants with load concentration varying within the usual range.

Omitting results for Lockbourne and Great Lakes, the average overall plant BOD removal for plants in Division I was 91.4 per cent, a value that

TABLE VIII.—Trickling Filter Operation. Single Stage, Deep, No Recirculation

Plant	G.C.D.	BOD (p.p.m.)			Nitrite +Nitrate N in Final (p.p.m.)	Filter Operation				Overall BOD Reduction (%)
						M.G.A.D.	Lb. per Acre-Ft.			
		Raw	Settled	Final			Applied	Removed	Per Cent Efficiency	
Turner	119	212	149	14	—	1.63	253	229	91.6	93.4
Sheridan	78	291	174	49	—	1.11	269	194	72.0	83.2
Swift	58	473	234	27	11.8	1.06	295	261	88.4	94.3
Campbell	50	427	265	22	17.4	1.15	363	333	91.7	95.0
Crowder	68	430	283	29	—	0.96	377	338	89.7	93.2
Leonard Wood	47	547	277	28	19.5	1.00	377	339	90.0	94.9
Benj. Harrison	94	257	148	22	1.5	2.78	429	365	85.2	91.5
Fitzsimons G. H.	67	390	312	68	0.9	0.80	720	573	78.2	82.6
Lockbourne	90	285	145	32	—	4.48	903	700	77.8	88.7
Gt. Lakes	66	390	306	89	—	5.66	2,130	1,510	71.0	77.2

compares favorably with best municipal trickling performance.

Many minor improvements were made by the operator at Camp Crowder that contributed to efficiency. A list of these is of interest as being indicative of the type of modification found to be useful by an enterprising operator of a World War II sewage treatment plant—one that was generally conceded to be originally well-designed and constructed.

(a) Installation of a sludge cleanout connection in sludge piping.

(b) Construction of a crane for handling grease from the intercepter.

(c) Installation of drain lines from the drip traps.

(d) Construction of chemical feed tank for applying alum and borax to the sludge.

(e) Installation of an extra waste gas burner.

(f) Decking over all open flumes.

(g) Installation of hot water tank for cleaning and washing of units and equipment.

(h) Construction of wooden sluice gates at dosing chambers.

(i) Addition of hand rails and concrete walks around units for safety.

(j) Provision for stream of sewage to impinge upon edge of filter bed in order to wash *Psychoda* larvae down wall.

(k) Piping of hot water to laboratory.

(l) Addition of cleanout hand-holes at suction side of sewage pumps at lift station.

Four rotary filters were installed at Fitzsimons. Only the three small filters were used in normal operation at the period of investigation. The large filter was installed to handle expected additional population and laundry waste. The organic load was higher than normal for low-rate filters, and performance was about in line with loading.

The main plant at Great Lakes afforded an interesting example of performance of a heavily loaded filter that was originally designed for low rate of load application. The primary and secondary sections of this plant were designed for different populations; in actual operation, however, all sewage was routed through filters. These units had fairly coarse media and were able to handle the load with fair efficiency. High degree of treatment was not considered necessary in view of dilution afforded the effluent by

Lake Michigan. Primary settling performance was substandard; three settling tanks were rebuilt in order to improve settling and to eliminate conditions conducive to septicity. Preaeration equipment at primary settling tank influent was installed subsequent to the period of operation investigated.

At Fort Sheridan infiltration and grease were not excessive; no laundry waste entered sewers except a small amount from officers' quarters. Plans were in effect at the time of survey for installation of recirculation facilities that would reduce detention periods in settling tanks. Poor workmanship was the cause of considerable leakage in an inverted siphon connecting the Parshall flume and filter dosing chambers. This structure was subsequently replaced with an open channel of reinforced concrete. An unusually low efficiency in filtration occurred. It is believed that this is to be attributed to the following factors: (a) excessive primary detention with septic filter influent; (b) clogging of media—pooling occurred at various times and control measures such as resting and chlorination were instituted; and (c) high rates as a result of intermittent dosing. With discharge through nozzles taking place for only 4.5 minutes out of 25, a rate of about 9 m.g.a.d. occurred during the peak flow period—a value much larger than in other plants of the division.

Deep Filters With Recirculation

Results of performance of sewage plants with deep filters and utilizing recirculation are presented in Table IX. Of the eleven posts represented, seven were located in the South, and the remainder were in the central part of the country. All plants were at army posts. Three of the plants (Buckley Field, Camps Claiborne No. 2 and Gordon) were loaded in the normal range of standard rate filter plants. Other plants had higher load concentration. A number of these were loaded in the so-called "intermediate zone" between high rate and standard rate loading.

As based upon actual population, post sizes varied from 9,000 at Boca Raton AAF to 52,200 at Fort Knox; corresponding flow ranged from 0.51 m.g.d. to 3.20 m.g.d. Average per capita sewage flow was 66 gallons.

The plant at Camp Callan afforded an excellent example of performance of a heavily loaded filter utilizing a

TABLE IX.—Trickling Filter Operation. Single Stage, Deep, With Recirculation

Plant	G.C.D.	BOD (p.p.m.)				Recirculation (%)	Nitrite + Nitrate N (p.p.m.)	Filter Operation				Overall BOD Reduction (%)
								M.G.A.D.	Lb. per Acre-Ft.			
		Raw	Recirc.	Settled	Final				Applied	Removed	Per Cent Efficiency	
Claiborne No. 2	45	456	355	156	31	33(a)(b)	—	1.52	245	206	84.2	93.3
Buckley	78	325	233	168	23	51(a)	—	1.81	382	346	90.4	92.8
Gordon	55	450	450	275	70	164(c)	—	3.81	555	413	74.6	84.5
Boca Raton	57	217	69	68	16	358(a)	—	14.9	1,170	1,095	93.5	92.8
Carson	58	368	368	255	45	155(b)	2.0	10.2	1,180	972	82.3	87.8
Claiborne No. 1	85	368	368	211	71	24(b)	1.2	1.52	1,240	823	66.3	80.8
Knox	61	332	217	134	24	77(a)	1.9	8.82	1,560	1,390	89.2	92.7
Drew Field	73	302	265	132	34	95(a)(b)	0.9	18.5	1,950	1,505	77.0	88.7
Forrest	67	321	321	234	70	172(b)	—	22.1	2,530	1,780	70.2	78.3
Jackson	68	319	319	218	73	128(b)	0.8	18.1	2,870	1,910	66.3	77.2
Callan	75	369	235	197	77	85(a)(b)	—	25.7	5,750	4,280	74.5	79.3

(a) Through primary settling tank.
(b) Through secondary settling tank.
(c) Around filter only.

relatively low recirculation ratio. Sewage was pumped to the plant intermittently. Grease in the influent was negligible and no laundry waste was present. Excess capacity at one of the lift stations caused frequent periodic surges of flow at the plant. This excess capacity was also conducive to septicity, which in part accounted for comparatively low BOD removal in primary sedimentation. The filter at Callan was loaded more heavily than any other filter in the group, yet its removal together with that of secondary settling, was comparatively higher. Excellent performance at Callan, in part, may be attributed to the warm equable climate of Southern California. From a study of results at Callan, it may be concluded that under favorable circumstances a high-rate filter plant with typical military sewage can handle almost twice the load specified by the Engineering Manual for high-rate filters, and yet give a removal of 75 to 80 per cent.

The plant at Drew Field was placed in operation in February, 1943. A battery of three Imhoff tanks was added in November, 1943. The population at the post, however, was not increased as had been expected, and the Imhoff tanks were not used as regular treatment units during the period of the survey. Sewage arrived at the plant intermittently from three lift stations. An excessive amount of grease occurred in raw sewage which was largely removed in primary settling tanks. Nozzles on the rotary filter distributor were of the centrifugal type with removable cover. They were connected to distributor arms through a half-union, 90° street ell, short nipple, and pipe clamp. Ventilation was provided consisting of two forced draft blowers for each of the two filters. Air was withdrawn from the filters by the blowers through a central well. The Drew Field plant provided another example of a filter with a loading that fell into the intermediate zone between the usual ranges for standard and high-rate plants. Performance, too, was intermediate between that of standard and high-rate filters. An unusually large removal occurred in the primary tanks.

Some difficulty with grease was encountered at Camp Gordon; this was attributed to unsatisfactory design of grease intercepters at mess halls. Scum boxes at the effluent of primary settling tanks operated successfully and grease content in primary effluent was small. It was estimated that 40 to 50 gallons of scum were removed daily. Difficulty also was experienced with sand that entered the sewer system through low manholes and broken sewer lines.

Removal of organic matter in primary settling at Fort Jackson was about average, however, the secondary section gave performance somewhat lower than average for the loading. This is probably to be attributed to septic plant influent and to effect of supernatant from digesters which was returned. A significant improvement in performance was noted subsequent to installation of additional digester capacity in September 1943.

The record of operation of the sewage plant at Fort Knox afforded an outstanding example of the value of skilled and intelligent operation in attainment of effective treatment.

Shallow Filters With Recirculation

The eight plants with shallow filters (Table X) form a fairly homogeneous group from the standpoint of design. Three of the posts, Forts Bragg, Sill, and Keesler AAF, were located in the South. All plants were at army installations: all were designed as high-rate filters.

As based upon actual population, post sizes varied from 8,940 at Kearns to 48,500 at Bragg. Flows ranged from 0.76 m.g.d. at Warren to 3.67

TABLE X.—Trickling Filter Operation. Single Stage, Shallow, With Recirculation

Plant	G.C.D.	BOD (p.p.m.)				Recirculation (%)	Nitrite + Nitrate N (p.p.m.)	Filter Operation				Overall BOD Reduction (%)
								M.G.A.D.	Lb. per Acre-Ft.			
		Raw	Recirc.	Settled	Final				Applied	Removed	Per Cent Efficiency	
Kearns	87	273	90	58	21	1050(a)(b)	11.3	20.8	792	705	88.8	92.3
Kilmer	98	201	128	89	44	186(a)(b)	—	11.4	1,530	1,030	67.0	78.2
Myles Standish	63	537	220	138	54	459(a)(b)	—	14.2	2,030	1,660	81.3	90.0
Dix	58	348	177	—	28	282(a)(b)	—	14.4	2,320	2,080	89.9	92.0
Keesler	81	218	119	115	30	126(a)	—	11.1	2,370	2,060	86.4	86.0
Bragg	76	356	169	147	61	415(a)(b)	Tr.	29.2	4,340	3,500	80.7	82.9
Sill	70	305	231	175	85	51(a)	—	16.4	6,450	4,060	63.0	72.2
F. E. Warren	74	429	429	359	173	277(b)	—	31.9	8,520	4,300	50.5	58.0

(a) Through primary settling tank.
(b) Through secondary settling tank.

m.g.d. at Bragg. Average per capita sewage flow was 76 gallons.

Soil was sandy at Fort Bragg, and with the old sewer system of this permanent post, the grit detriter served a useful function. Two large coagulating basins with stirring mechanisms were installed ahead of primary settling tanks. The coagulating basins provided a detention period of about 2.5 hr. at average flow. No chemical coagulants were used. The basins did not improve settling performance, which was low. On the other hand, the aerating and mixing action of the basins appeared to have some value in maintaining high efficiency of biological treatment on the filters.

Fort Dix, as in World War I, was a Staging Area, and unusual conditions of loading were imposed upon the sewage treatment plant. Population shifts were sudden and extreme; at certain periods, the changes took place on a semi-weekly and even daily basis. Flow perhaps might be about 2.0 m.g.d. for several days and then increase to 3.0 m.g.d. for a week. Variations in population were even more extreme. The new high-rate plant at Fort Dix was completed in April, 1943, to supplement the old plant which was overloaded throughout 1942. The new plant, which was constructed on a plot adjacent to the original plant, also provided capacity to handle waste from a new post laundry.

Removal of BOD in primary tanks was rather low, but this was more than offset by exceptionally high efficiency of filtration. The filters at Dix received approximately four times the organic load per unit volume usually applied to low-rate plants, yet BOD removal compared favorably with that attained in standard filter plants. The outstanding performance of the plant at Fort Dix pointed up the adaptability of the high-rate filter to extreme conditions of loading that occurred in staging areas.

The record of sewage treatment at Camp Kearns is of interest since the filter unit there, which was designed for high rate of operation, was loaded to only a small fraction of capacity. Sewage arrived at the plant by gravity. During heavy precipitation the flow at the plant was increased by about 500,000 gallons daily. Considerable amounts of sand were removed from the grit chamber. No provision for velocity control was made in the grit removal channels and these units were not entirely satisfactory. Grease content was low; and laundry waste was not a problem.

The recirculation ratio, 10.5, was high; this may be attributed to fixed recirculation capacity and lower sew-

age flow than provided for in design.

The record of sewage treatment at Camp Kilmer is indicative of the difficulties that beset operation in a plant subjected to the extreme population fluctuations that occurred in military staging areas. Loading on the average was less than two-thirds of design capacity. Average values do not, however, convey an adequate description of loading; population would change from (say) 5,000 to 40,000 overnight. Treatment units that had been nearly idle, would be taxed to capacity within a space of a few hours. The situation demanded the utmost flexibility of operation.

Performance of the primary section of the plant was normal; long detention periods occurred. The reduction of BOD and SS that took place in the filters and secondary settling units, however, was definitely substandard. Numerous investigations were made and it was concluded that the poor performance of the filters, which were loaded at about three-fifths the rate specified as a design criterion in the Engineering Manual, was attributed to a clogged condition resulting from a flourishing growth of sulfur bacteria, *Thiobacteriales,* principally *Beggiatoa alba.* It was found that the sulfur-utilizing organisms could be killed by superchlorination; but after being killed, the organisms would not slough from the media. Only with a considerable passage of time did the dead growths wash off and pass through the filter. With the cleaning of the filters, performance improved. Excavation of pipes connecting the primary clarifier with the Biofilter brought forth the fact that sulfur organisms had been thriving in underground conduits and in the surrounding soil.

Two-Stage Filter Plants

An analysis of loading and performance at nine two-stage trickling filter plants is presented in Table XI. These installations could not be treated as a homogeneous group since a considerable difference in design was exhibited. Almost every conceivable scheme of recirculation was represented. Loading varied over a wide range. Some plants utilized intermediate settling between the first and second stage of filtration, others did not. Indeed, the only feature of design in common for all plants was the arrangement of filter units in series.

A considerable variation of population occurred at Camp Forrest during the twelve months of operation investigated. The plant at this post was enlarged two times. The first addition, which was placed in operation in March, 1941, consisted of one primary settling tank, one high-rate filter, and two secondary settling tanks. A

TABLE XI.—Trickling Filter Operation; Two-Stage

Plant	G.C.D.	BOD (p.p.m.)				Total Recirculation (%)	Nitrite + Nitrate N (p.p.m.)	Second Stage Filter				Overall BOD Reduction (%)
								M.G.A.D.	Lb. per Acre-Ft.			
		Raw	Recirc.	Settled	Final				Applied	Removed	Per Cent Efficiency	
Robinson	59	358	239	167	27	—	—	1.71	192	128	67.1	92.6
Forrest	115	215	215	—	15	—	—	2.29	—	—	—	93.3
Sill	70	305	231	175	26	—	—	4.64	658	455	69.5	91.5
Gordon	71	397	397	258	48	—	5.0	7.69	—	—	—	88.2
F. E. Warren	74	429	429	221	66	343	7.0	5.97	678	431	63.6	84.8
Riley	102	244	121	92	34	470	—	16.7	714	364	51.1	86.1
Willow Grove	—	144	73	40	11	453	—	16.2	910	397	73.8	92.6
Topeka	88	210	126	86	15	256	—	18.3	930	687	73.8	92.8
Roberts	57	378	169	149	53	495	—	45.6	5,280	3,370	64.0	85.8

second addition consisting of two standard filters, three final settling tanks, a secondary digester, and nine sludge drying beds was completed in August, 1943.

Infiltration into the sewer system at Camp Forrest was excessive, and the effect may be noted in the large volume of sewage flow per capita. Grease at times was excessive, the difficulty being attributed to inadequate trap maintenance. Laundry wastes also were larger than normal.

An increase in the per capita production of BOD during winter months was evident at Camp Forrest. This phenomenon, which was noted at a number of other divisional training posts, was attributed to decreased amouts of bivouacking during colder months. Lack of analytical data unfortunately made it impossible to analyze completely the performance of first- and second-stage filters.

A number of schemes of recirculation were used in connection with the first stage of filtration. These included recirculation (a) from effluent of secondary settling tank to filter influent; (b) from filter effluent to filter influent; (c) from filter effluent to primary settling tank influent. No recirculation was used about the second-stage filters.

The two-stage filter plant at Camp Roberts accomplished an extraordinary amount of removal of organic material from sewage upon filters that were heavily loaded. Infiltration was moderate, occurring principally during the rainy season. Grease was not excessive at the time of the survey. A program of instruction for mess-hall personnel was effective in improving maintenance of grease traps. Laundry wastes were present but not excessive. Sewage temperature at Camp Roberts, which was situated in southern California, was higher than at other two-stage filter plants, and it is likely that this was a significant factor in the attainment of high efficiency in the filter units. The population loading of the plant during the 18 months of operation investigated was fairly uniform, but diurnal variation in flow at the plant was marked. The per capita flow was low and sewage was somewhat more concentrated than at most two-stage filter plants.

Filter loading at Camp Roberts was highest of all trickling filter plants surveyed. Nearly three times the BOD load specified in the Engineering Manual was applied to the primary filter.

At Camp Joseph T. Robinson, a World War I standard trickling filter without final settling was modernized to form a two-stage plant. Primary settling tanks consisted of (1) two rectangular Doten tanks, revamped and equipped with sludge collecting mechanism and (2) a modern, circular tank with usual appurtenances. The first-stage filter was a new shallow high-rate unit with a rotary distributor.

The efficiency of the plant at Camp Robinson was impaired by poor supernatant which was returned to the head of the plant. The volume of supernatant returned averaged 17,000 g.p.d.

The two-stage trickling filter plant at Fort Sill had a remarkable record of performance. It successfully treated sewage from a considerably larger population than was provided for in the original design. Sewer gradients were moderate and infiltration normal; sewage arrived at the plant in a fresh condition.

The first-stage filters at Fort Sill received a BOD load of 6,450 lb. per acre-ft. as based upon settled raw sewage. These filters, together with intermediate settling, removed 63.0 per cent of this applied load, corresponding to a removal of nearly one-half (47.8 per cent) of the entire BOD load of the plant. This high degree of efficiency is to be attributed to the following

factors: (a) warm temperature without extreme seasonal variations; (b) rather small size of media with large contact area; (c) absence of grease in excessive amounts; (d) uniform application of flow to filters, which operated at a constant rate of 16.4 m.g.a.d. regardless of the rate of flow into the plant; and (e) absence of returned supernatant, which was routed to lagoons.

The two-stage filter plant at Fort Francis E. Warren did not give as high a degree of treatment as other two-stage plants with similar design and loading. The plant was constructed in two major phases.

The additions included a grease and grit chamber, a final filter, and a final clarifier. Additional digester capacity also was provided, and the new digester, a rectangular, earth-bank-covered tank, was placed in operation in January, 1943. Provision was made for heating this unit, but heat was not utilized until the middle of 1943.

During the operating period at the Fort Warren plant investigated in this report (January, 1943 to August, 1944), two-stage filtration was utilized. In this period the grease content was normal; grease traps serving mess halls were cleaned regularly. No laundry wastes entered the sewage plant; a separate laundry waste treatment plant was operated.

The sewage at Fort Warren was more concentrated (429 p.p.m. BOD) than at any other two-stage filter plant studied.

The efficiency of the final filter was low as compared to final filters in other similarly loaded two-stage plants. Flow (including recirculation) to the secondary filter at Warren was maintained at a constant rate. Unloading periods were observed. The BOD loading as computed upon an overall basis—raw settled sewage BOD per acre-ft. of total filter volume—was 1,180. This value was about twice the usual design load for standard filters. The Warren plant, however, failed to turn in a performance comparable to heavily loaded plants in the standard filter range. In connection with interpretation of operating results at Fort Warren, attention should be directed to the fact that the mean annual temperature in Wyoming was notably lower than that at the majority of the two-stage filter plants investigated.

Generalization of Results of Filter Performance

The data pertaining to trickling filters at military installations, presented in the preceding sections, cover a wide range of conditions. In Figures 11 and 12 are shown the relationship bebetween BOD loading and performance for single-stage filters. A general decrease in efficiency may be observed with higher loadings. It should be noted that different scales are used for the two figures. Figure 11 includes most of the low-rate filters; Figure 12 includes most of the high-rate filters.

The simplest and most direct measure of filter loading is the average weight of BOD in the raw settled sewage applied to the filter per day. This does not include recirculated BOD. To be sure, recirculation has an important bearing upon performance, but this can better be taken into account in another fashion. Results indicate that recirculated BOD has a "treatability" that is essentially different from the BOD in raw settled sewage. Consequently, the two substances cannot be indiscriminately combined to form a useful measure of loading.

The relation of filter efficiency and filter loading can be studied in the summary tables for the four types of filters (Tables VIII to XI). These results have been combined in Table XII to indicate loadings from 253 to 8,250 lb. per acre-foot. In Figure 13 the loading-efficiency relationship is presented, with BOD loading expressed

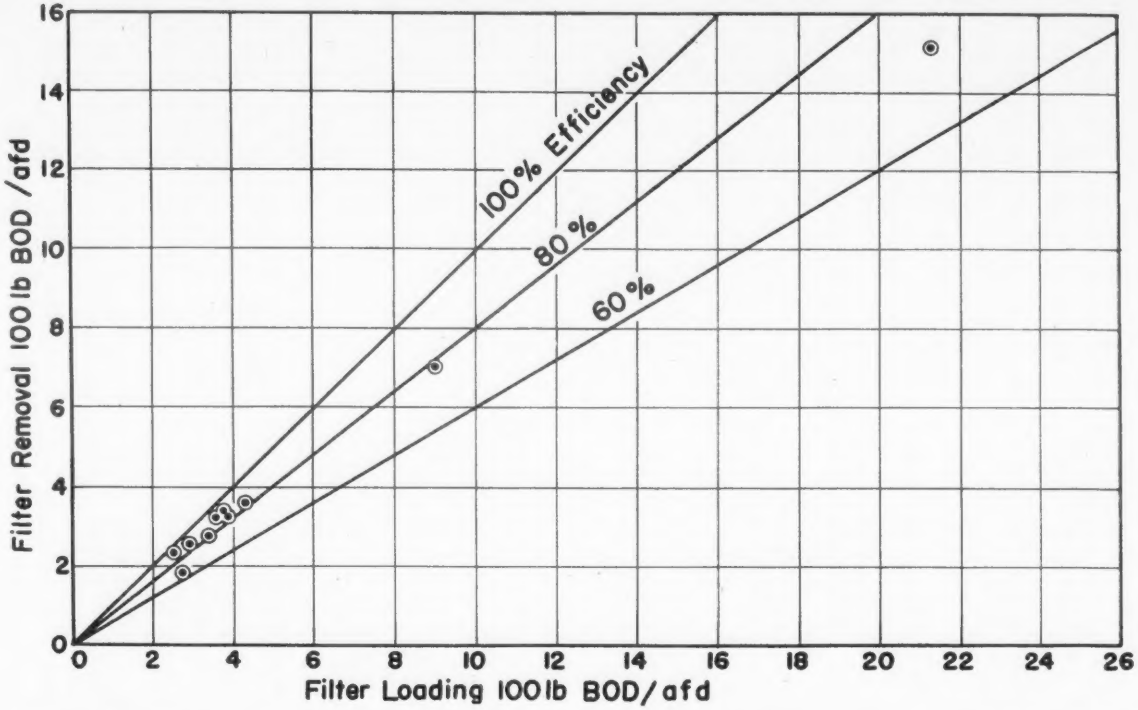
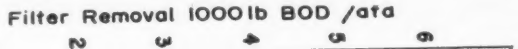


FIGURE 11.—Relation between loading and performance in plants without recirculation. Loading is based upon raw settled sewage. Removal includes that in settling tanks subsequent to filtration. Each point represents average for a single-stage plant for period of study.



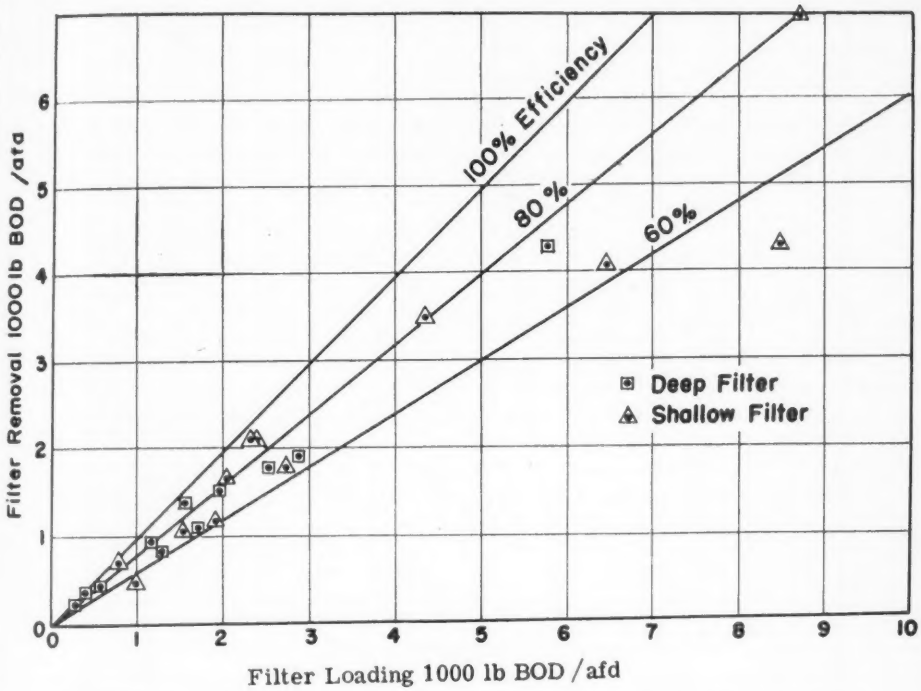


FIGURE 12.—Relation between loading and performance in plants with recirculation. Loading is based upon raw settled sewage. Removal includes that in settling tanks subsequent to filtration. · Some points represent first stage filtration in two-stage plants.

TABLE XII.—Summary of Trickling Filter Plant Operation

No. Plants	Group Designation	Range of BOD Loading (lb./acre-ft.)	Filter and Sec. Settling, BOD Eff. (%)	Overall BOD Reduction (%)
4	Deep, No Recirc.	253 to 429	86.9	92.2
4	Deep, Recirc.	245 to 1,170	85.7	90.8
8	Two-Stage	192 to 930*	66.5*	90.2
4	Shallow, Recirc.	792 to 2,320	81.8	88.1
4	Deep, Recirc.	1,190 to 1,950	78.7	87.5
3	Deep, No Recirc.	720 to 2,130	75.7	82.8
3	Deep, Recirc.	2,530 to 5,750	70.3	78.3
4	Shallow, Recirc.	2,370 to 8,250	70.1	74.8

* Second Stage.

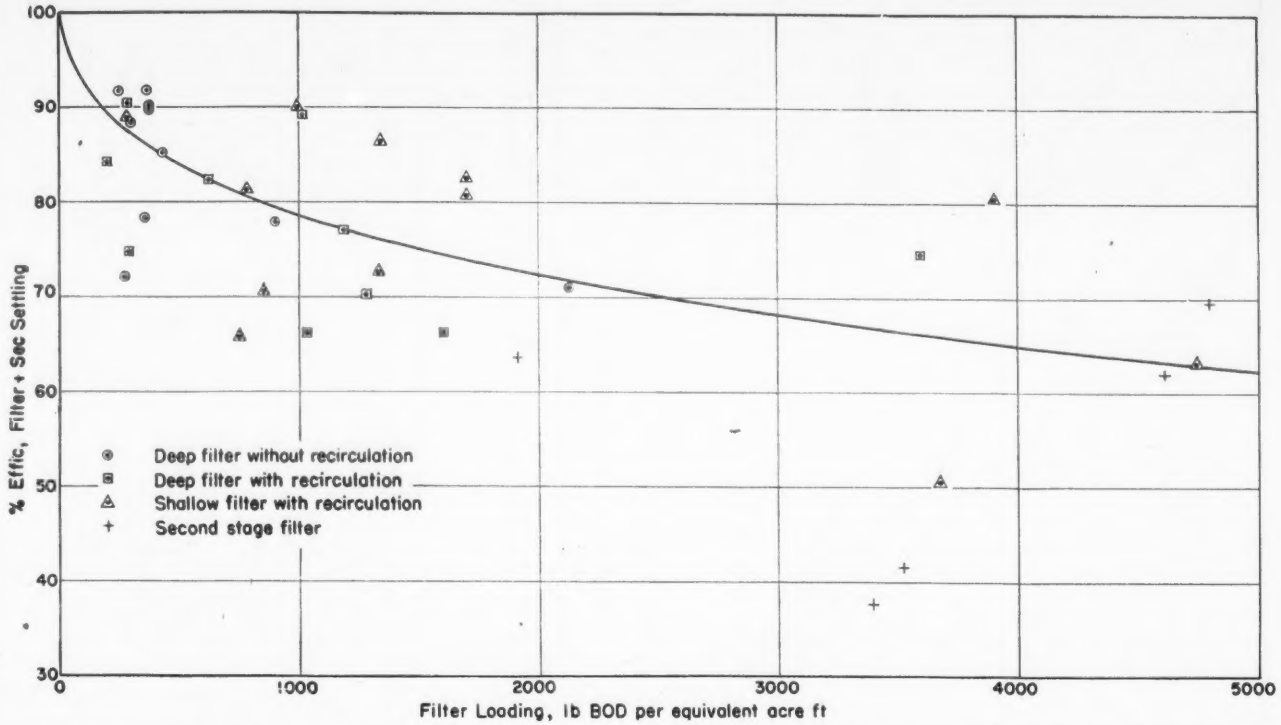


FIGURE 13.—Relation between filter loading and efficiency for all filter plants. Loading is expressed upon an equivalent basis in accordance with filter efficiency formulation. Points representing second-stage filter performance are plotted as equivalent first-stage points, but were not considered in establishing curve.

as pounds per "equivalent acre-foot," which is explained later.

Nitrification

In normal operation at the majority of military sewage plants, routine nitrogen determinations were not made. In order to obtain information relating to nitrification occurring in various types of filters, a special study was made at a selected group of plants during the last four months of 1944.

Since post strengths generally declined during September to December, 1944, the loading at many of the plants differed somewhat from that during the main period of investigation (January, 1943, to August, 1944).

The first group, deep filters without recirculation, gave 92 per cent overall reduction. Their operation is characterized by high nitrification and low volumetric and organic loads applied.

Recirculation enabled the loads to be increased to 1,170 lb. per acre-ft., and in general results improved as recirculation ratios increased. At Boca Raton a filter rate of 14.9 m.g.a.d., including 358 per cent recirculation, gave an effluent with only 16 p.p.m. BOD.

Recirculation thus improved considerably results from a deep filter at 1,170 lb. per acre-ft. application, but the rate of recirculation seems too high for such a dilute sewage.

Next, two-stage filters gave excellent results but most of the work was done in the first stage.

For higher loadings, up to around 2,000 lb. per acre-ft., shallow filters with considerable recirculation, from 280 to 1,050 per cent, were able to produce around 90 per cent overall reduction of BOD and considerable nitrate with the highest rate of recirculation, at Kearns.

Finally, at high rates of loading, from 2,370 to 8,250 lb. per acre-ft., results were quite inferior to those produced by a low-rate standard filter.

It is interesting to note that loadings above 2,000 lb. per acre-ft. resulted in effluents containing BOD around 70 p.p.m., overall removals of 78 per cent, and no nitrification. This is far from the quality of an effluent from standard low-rate filter operation, even though the loading is less than the 3,000-lb. rate used in design of high-rate filters.

None of the filters loaded over 1,000 lb. per acre-ft. produced nitrification.

It seems difficult to believe, therefore, that effluents from high-rate filters, dosed at rates higher than 1,000 lb. BOD per acre-ft. per day, are just as completely treated as effluents from low-rate standard filters. However, a precise comparison cannot be based upon the 5-day BOD as a measure of results accomplished.

A statistical analysis of the data for all plants indicates that recirculation in nearly any form brought about an improvement in performance that was significantly larger than the differences in performance noted between different schemes of recirculation.

When the recirculation ratio is one, the flow, on the average, passes through the filter twice; more generally the average number of passes is given by the recirculation ratio plus one.

If, for example, the recirculation ratio was 2.5, then the average number of passes would be 3.5. The organic matter has less recirculation, since it is being constantly removed. It was found that the number of passes of organic matter could be estimated from the following formula:

$$F = \frac{1 + \frac{R}{I}}{\left[1 + 0.10\,\frac{R}{I}\right]^2}$$

The quantity that primarily determines efficiency in a trickling filter is w/VF, in which w = weight of BOD in settled sewage (lb. per day),

V = volume (acre-ft.) and F = number of passes of organic matter.

The per cent efficiency is given by the equation:

$$E = \frac{100}{1 + 0.0085 \sqrt{\frac{W}{V F}}}$$

While this equation is empirical, it does conform to reasonable expectation that with low loading efficiency will approach 100 per cent, and with high loading efficiency will approach zero, asymptotically. Moreover, the form of the equation was found to fit sewage plant data more precisely than any other equation with two arbitrary constants. The same form of equation has been found to apply in connection with the analysis of contact aeration and activated sludge plant performance.

Recirculation Factor

The recirculation factor has properties that are of significance. The value of the recirculation factor F increases with the recirculation ratio, R/I, until a maximum value is attained.

When the constant p in the equation:

$$F = \frac{1 + \frac{R}{I}}{\left[1 + (1 - p)\frac{R}{I}\right]^2}$$

has the value 0.90, the following numerical relationship exists between the recirculation factor F and the recirculation ratio R/I:

Recirculation Ratio (R/I)	Recirculation Factor (F)	Recirculation Ratio (R/I)	Recirculation Factor (F)
0.0	1.00	4.0	2.55
0.5	1.36	6.0	2.73
1.0	1.65	8.0	2.78*
2.0	2.08	10.0	2.75
3.0	2.37	15.0	2.56

* Maximum.

Efficiency of Second-Stage Filters

In two-stage filters the BOD in the effluent of the first stage is considerably less "treatable" than that in raw settled sewage. The "treatability" depends upon the proportion of the initial organic matter removed in the first stage, because the filter growths tend to assimilate the more readily available organic compounds first. Consequently, if (say) 1,000 lb. of first-stage filter BOD are applied to a second-stage filter, the efficiency will be distinctly less than if 1,000 lb. of BOD in the raw settled sewage were applied to the same filter.

It is seen that with $p = 0.90$, the greatest effect that recirculation through a given filter can produce is to make the effective volume 2.78 times as large as the actual volume.

The minimum equivalent volume is obtained when the first- and second-stage filters are made about the same size. Although the exact solution indicates that a somewhat better balance occurs when the second filter is made slightly larger or is given more recirculation, the advantage is not sufficiently marked to offset the convenience of having duplicate units with all dimensions and pumping capacities identical.

CONTACT AERATION PLANTS

Selection of Plants

Contact aeration plants were constructed at about fifty army installations and at a few navy installations. Except for minor variations, these plants were all of one type, but modifications or additions often had to be made in order to secure satisfactory operation. Under favorable conditions of loading and sewage concentra-

tion, good effluents were obtained, with overall removals of BOD averaging 80 to 95 per cent in the plants selected for study. When strong stale sewage had to be treated, however, or where difficulties developed in the aeration system originally installed, effluents were unsatisfactory, odors became intense, and first-aid measures had to be applied in order to keep the plants in service. By close and continuous attention to operation or by suitable remodeling or additions, practically all plants were eventually enabled to continue in operation.

Arrangement of Plants

The type of contact aeration plant constructed at military installations comprised (1) preliminary settling tanks, (2) primary aeration units in which vertical asbestos plates are supported above horizontal pipe-grid aerators, (3) intermediate settling tanks, (4) secondary aeration units identical as to arrangement but not always as to size with the first-stage units, and (5) final settling tanks. The bases of design specified in the Army Engineering Manual were:

(1) Preliminary settling—2.5 hr.
(2) Primary aeration—156 sq. ft. of surface per lb. of BOD applied daily.
(3) Intermediate settling—1.5 hr.
(4) Secondary aeration—same loading as for primary aeration.
(5) Final settling—2.5 hr.

The tanks were frequently grouped on three sides of a rectangle, with the primary settler and primary aerator in series on one side, the intermediate settler at right angles on the second side, and the final aerator and final settler in series on the third side, the central area being used for the housing of control devices, valves, and sludge receivers.

The asbestos plates which provided the contact surface were usually flat but sometimes corrugated. They were about ¼ in. thick, usually 4 by 8 ft. in plan, and hung or supported at right angles to the direction of displacement with approximately 1.5-in. spaces between the plates. The top of the plates was submerged about 4 in. Air was admitted below the plates by a pipe-grid perforated with orifices of 1/16 to ⅛ in. diameter spaced to direct the rising air bubbles between the plates, and sufficient in number to provide uniform distribution of air.

Below the air-grid, the tanks were constructed with hopper bottoms for sludge collection and removal. In spite of the slope of the hoppers, however, sludge removal was not always found to be complete. At certain plants (Hondo and Waco No. 1), therefore, the hopper was later filled in so that sludge could not accumulate below the contact units. In some larger plants (such as Hood) sludge-collecting mechanisms were installed in troughs under the air-grids.

The individual relations to BOD efficiency, based on settled sewage, were as follows:

Post	BOD Efficiency (%)	Air Supply (cu. ft.)		Net Aeration Period (hr.)	Contact Surface (lb. of BOD applied per 1,000 sq. ft. per hr.)
		Per Gallon	Per lb. of BOD removed		
Hondo	60.4	1.35	2,410	1.72	3.56
Kingsville	70.8	1.75	3,170	2.36	1.44
Roswell	72.8	2.15	1,890	2.67	3.21
Greenville	76.8	1.99	2,250	2.84	2.40
Rucker	85.8	4.21	2,990	6.74	0.84

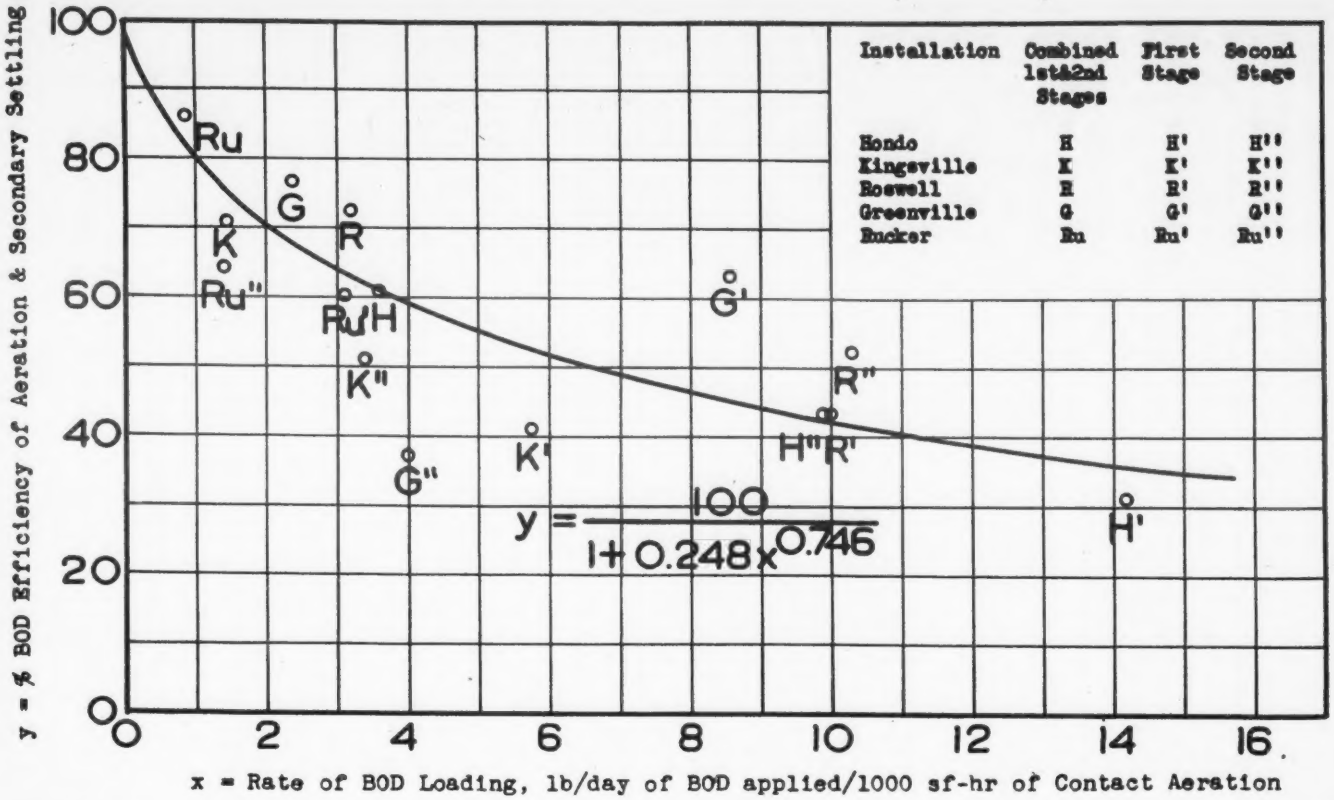


FIGURE 14.—Efficiency of contact aerators. Plotted points indicate performance of first stage, second stage and combined first and second stages at five contact aeration plants.

The relations of BOD removal and loading are shown in Figure 14. These relations depend upon the contact per 1,000 sq. ft. per hour.

It is evident that the efficiency of the process is dependent upon (1) the total amount of biological film, which is proportional to the area of contact, and (2) the time of contact of the sewage with the contact surface, as measured by the detention period in the aeration basins. The maintenance of aerobic conditions in the flowing sewage is, however, a prerequisite.

Figure 14 may be used to ascertain the performance that normally would be expected with a plant designed in accordance with criteria set forth by the Army Engineering Manual.

The difficulties of operation of contact aerators, high maintenance labor requirements, and more than occasional odor nuisances indicate that contact aerators are less desirable for use in military camps than are trickling filters. No superiority of contact aeration over activated sludge has been demonstrated.

ACTIVATED SLUDGE PLANTS

Selection of Plants

Activated sludge plants were constructed at about twenty army installations and at a number of navy installations. Although these included a number of mechanical aeration plants at smaller military camps, the data available for only the four diffused air and the single combined mechanical aeration and diffused air plants (Great Lakes) listed in Table XIII met the requirements for inclusion in this survey. Of the plants selected for study, all the army plants were of the diffused-air type.

Basis of Design

According to the Army Engineering Manual, the following displacement periods in hours based upon the 24-hr. average rate of flow were used in de-

TABLE XIII.—Operating Results at Activated Sludge Plants

Plant	Population Design	Actual Population	Design Flow (m.g.d.)	Actual Flow (m.g.d.)	Aeration Period (hr.)	Air (cu. ft. per gal.)	Air (cu. ft. per lb. BOD removal)	Mixed Liquor Susp. Solids (p.p.m.)
Butner	41,600	30,800	2.91	1.62	9.0	2.89	1,590	1,143
Gulfport AAB	22,600	17,100	1.58	1.18	10.3	1.95	1,620	1,592
Monmouth	12,800	17,200	0.90	0.63	10.9	2.90	1,585	1,497
Shelby No. 2	34,700	8,000	2.43	0.56	28.9	4.00	2,650	889
Gt. Lakes	27,400	22,000	1.92	1.49	12.0	1.52	690	845

Plant	5-day BOD (p.p.m.)			Removal (%)	Susp. Solids (p.p.m.)			Removal (%)
	Raw	Settled	Final		Raw	Settled	Final	
Butner	397	266	49	87.7	350	179	30	91.4
Gulfport AAB	224	175	31	86.1	172	113	40	76.7
Monmouth	354	284	63	82.0	360	208	131	63.6
Shelby No. 2	289	194	13	95.6	250	130	15	94.1
Gt. Lakes	363	280	37	89.7	376	195	35	90.7

signing units for activated sludge plants:

	Displacement Period (hr.)
Primary settling tanks	1.5
Aeration tanks	
Diffused air plants	8.0
Mechanical aeration plants	12.0
Final settling tanks	2.5

In designing the aeration tanks and final sedimentation tanks, an allowance of 25 per cent for sludge return was included in the average rate of flow.

General Data

The general data relating to the activated sludge plants studied are listed in Table XIII.

Shelby No. 2 produced an effluent with an average BOD of 13 p.p.m. and a suspended solids content of 15 p.p.m. This was the only plant in this group that produced an effluent comparable to that from a large well-operated municipal activated sludge plant. This plant, with the lowest loading in the group, gave overall removals of 95.6 per cent for BOD and 94.1 per cent for suspended solids.

Great Lakes gave the next best performance with overall plant removals of 89.7 and 90.7 per cent for BOD and suspended solids, respectively. The performance at Butner was slightly lower for BOD, 87.7 per cent, and slightly higher for suspended solids, 91.4 per cent.

At Gulfport, the average overall BOD removal fell to 86.1 per cent and the suspended-solids removal performance deteriorated to 76.7 per cent.

The poorest performance of all is that recorded for Monmouth, where the overall BOD and suspended solids removals were only 82.0 and 63.6 per cent, respectively. The poor results may have been caused, in part at least, by the discharge of photographic wastes into the sewage reaching this plant.

Most of the activated sludge plants operated with bulking sludge. The percentages of the time that the average sludge index for the month was over various limits are listed below for each of the army plants:

Post	No. of Months of Operation	Percentage of Time During Which the Average Sludge Index was Above the Stated Value			
		150	200	300	400
Butner	20	80	75	65	35
Gulfport AAB	16	75	69	56	56
Monmouth	16	69	62	56	56
Shelby No. 2	16	69	62	50	25

These data indicate that all of these plants produced bulking sludge during a considerable portion of the time, if bulking limits are set by municipal standards.

The differences between municipal and military sewage which should be considered as possible factors include: (a) irregular distribution of flow; (b) excessive grease contents; (c) higher BOD values and rates of biochemical oxidation; and (d) higher volatile content.

Chlorination of returned sludge was used at four of these plants to control sludge bulking. The dose used varied from 7.0 to 10.0 p.p.m. The period of chlorination varied from intermittent application for a day or two to continuous application.

Two curves (Figure 15) have been fitted to results of operation of activated sludge plants. The upper curve pertains to municipal sewage plants not greatly influenced by industrial wastes. The lower curve applies to the military plants excluding Monmouth. The shape and location of the two curves bring out clearly the differences in efficiency manifest between military and municipal plants.

Discussion

An examination of the data in the foregoing tables shows that activated

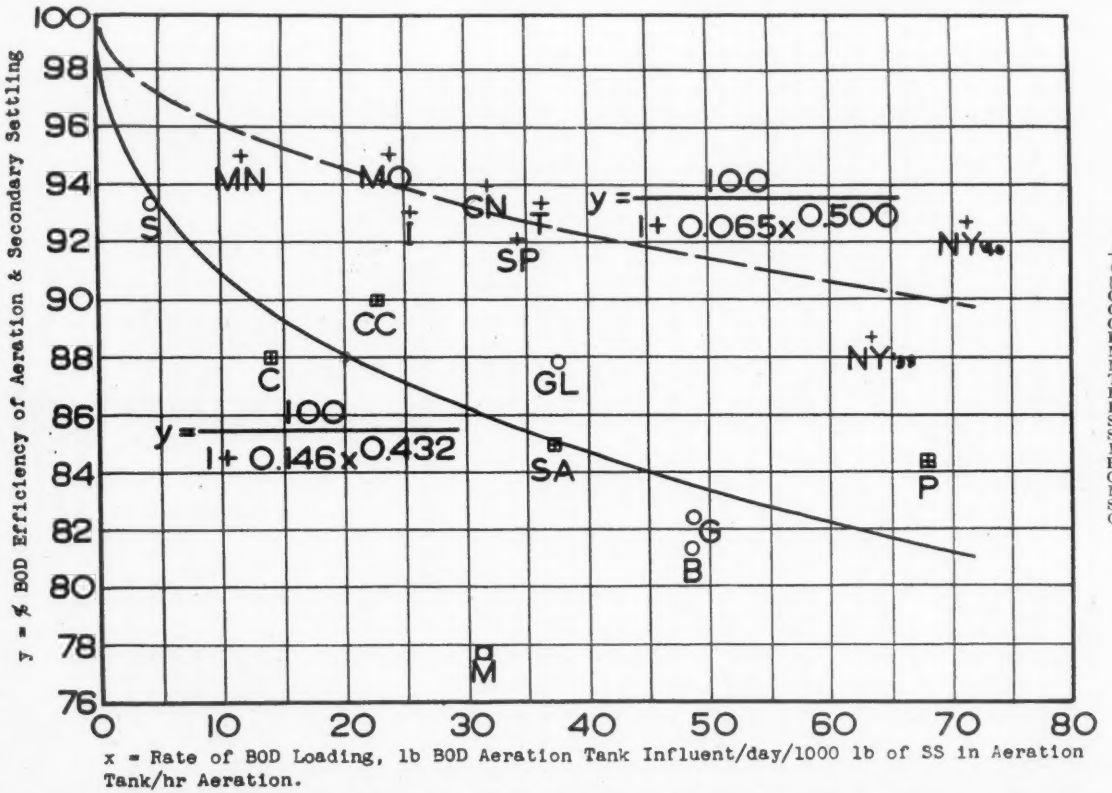


FIGURE 15.—Efficiency of municipal and military activated sludge plants. Points representing municipal plants are based upon operating results for one-year period. Upper curve is fitted to points representing municipal plants not greatly influenced by industrial wastes. Lower curve is fitted to points representing military plants excepting Monmouth.

sludge plants in military installations did not give higher percentages of removals of BOD or SS than did a number of other types of plants. Because of the large quantities of air used per gallon of sewage treated, these activated sludge plants, furthermore, were expensive to operate. The operating and analytical data obtained indicate that, as designed at present, activated sludge plants are not sufficiently flexible to handle the variations in flow and load that are expected in military posts. With the best available control and operation, very light sludge indices (over 200) were obtained during the greater part of the time. To prevent the loss of sludge over effluent weirs, application of chlorine or coagulants to the returned sludge and constant vigilance on the part of the operating staff were required. Many problems remain to be solved before smooth operation of military activated sludge plants can be assured.

SLUDGE DIGESTION AND DISPOSAL

Limited data were available for study of results of heated sludge digestion. Results are shown in Tables XIV and XV.

Of the trickling filter plants, the digestion space provided averaged 4.2 cu. ft. per capita based on the actual population served during the loading period. Similar figures were 11.2 cu. ft. per capita for the activated sludge plants and 1.5 cu. ft. per capita for the primary treatment plant. The Engineering Manual (January, 1943) stipulated design figures for sludge digester volumes of 3.0 cu. ft. per capita for trickling filter plants, 4.0 cu. ft. per capita for activated sludge, and 2.0 cu. ft. per capita for primary treatment plants.

All but one of the plants listed used two-stage digestion, while the one primary plant used single-stage digestion. Of the twenty tanks represented, thirteen were equipped with floating covers, four had fixed covers (one with stirring mechanism), and three were open. The temperature of the digesting sludge in heated tanks ranged from 90° to 98° F., averaging 93° F.

The quantities of solids in raw sludge were estimated from the suspended solids decrease through settling tanks. It was found that this method afforded a more precise estimate of

TABLE XIV.—Sludge Digestion Record

Post	Cu. Ft. Available	Cu. Ft. per Capita	Temp. (° F.)	Gal. Sludge per M.G. Sewage	Per Cent Solids Raw Sludge	Lb. Dry Solids per Cu. Ft. per Month	Lb. Dry Solids per M.G.	Per Cent Volatile
Campbell[1]	164,000	4.2	90	3,885	7.17	0.83	2,310	69.2
Crowder[2]	109,000	3.7	91	4,780	6.14	1.37	2,440	74.0
Fitzsimons[1]	30,000	4.5	98	5,640	2.86	0.60	1,346	80.3
Bragg[2]	199,000	4.1	98	8,440	2.03	0.81	1,430	79.4
Kilmer[2]	102,000	4.3	90	5,000	3.06	0.89	1,274	77.0
Butner[3]	230,000	7.5	90	14,300	1.50	0.39	1,796	73.6
Shelby No. 2[3]	117,700	14.8	90	14,100	1.47	0.25	1,730	—
Davisville[4]	19,600	1.5	98	7,640	1.56	1.66	974	74.7

[1] Low-rate filter.
[2] High-rate filter.
[3] Activated sludge.
[4] Primary sedimentation.

TABLE XV.—Gas Production, Digested Sludge, Sludge Beds

Post	Gas Production		Digested Sludge		Sludge Beds			
	Cu. Ft. per Cap. per Day	Cu. Ft. per Lb. Vol. Solids	Solids per cent	Vol. Dry per cent	Months per Yr. Used	Dosing (in.)	Inches Wet per Yr.	Lb. Dry Solids per Sq. Ft. per Yr.
Campbell	0.97	12.9	5.7	46.7	10	9	37.6	11.2
Crowder	1.79	14.5	6.3	53.4	12	6	51.0	16.5
Fitzsimons	1.32	18.3	4.4	61.8	10	9	43.0	11.8
Bragg	0.93	10.8	5.6	58.8	10	14	41.6	14.5
Kilmer	1.06	11.1	4.2	60.0	12	7	27.8	6.1
Butner	1.40	19.4	4.8	53.4	10	7	34.7	8.7
Shelby No. 2	—	—	3.3	50.7	5	—	23.0	3.9
Davisville	0.62	10.4	8.7	47.6	12	6	47.0	21.2[1]

[1] Glass covered.

amounts of sludge solids than direct measurement from sludge samples.

In the plants listed, the total solids in the raw sludge added to the digesters varied from 1.47 per cent for Shelby No. 2 (activated sludge) to 7.1 per cent for Campbell (low-rate filter). The raw volatile solids fall in the upper part of the range expected in separate municipal systems. As shown in the tabulation, this figure varied from 69.2 to 80.3 per cent, averaging 75.5 per cent.

Of the eight plants listed, sludge gas production figures were available at seven. Mean production of the six complete treatment plants was 1.25 cu. ft. per capita daily, while at the single primary treatment plant the corresponding figure was 0.62. The seven plants gave gas yields of 13.9 cu. ft. per lb. volatile matter added and 20.5 cu. ft. per lb. of volatile matter destroyed. Both of these figures are slightly higher than usual municipal experience. The average destruction of solids added to the digesters of the listed plants was 69.0 per cent of the volatile solids and 57.1 per cent of the total solids.

The digested sludge of the eight plants averaged 7.2 in pH, 5 per cent total solids, and 54.1 per cent volatile solids. The latter figure, while higher than general municipal practice, reflects the higher volatile solids content of military sewage.

All digested sludge was dried on conventional drying beds. The sludge beds were open with the exception of Davisville, the primary treatment plant, which had a glass cover. As indicated in the table, loadings were generally light, amounting to only 10.4 lb. of dry solids per square foot annually in the complete treatment plants, and 21.2 lb. of dry solids per square foot annually in the primary treatment plant with covered sludge beds. Accepted figures for municipal practice are 25 to 40 lb. per square foot annually. Of the open drying beds, the average sludge production in inches per year was 40. The corresponding depth for dried sludge was 7.6 inches per year.

At a number of plants, liquid digested sludge was distributed over land areas in the cantonment. This method of disposal was tried initially on an experimental basis at several posts in the Third Service Command, the Great Lakes Naval Training Station, and a number of other posts. The results appeared to justify the method from an economic standpoint under conditions existing at some military establishments. The medical aspects

of the problem were in general recognized by official personnel in Service Command and Navy Area headquarters. The danger inherent in an unrestricted program of wet sludge disposal without regard to such factors as (a) latitude, (b) soil condition (perviousness), (c) type of sludge (moisture and degree of digestion), and (d) wind direction and velocity were emphasized by wartime investigations demonstrating existence of parasitic organisms, such as *Ascaris lumbricoides* and *Tricuris trichiura,* in military sewage sludge. Wet sludge disposal at military hospitals might under unfavorable conditions be an exceedingly undesirable practice.

OXIDATION PONDS

A number of plants at military installations utilized oxidation ponds to attain secondary treatment. These units consisted of large open basins, 2 to 3 ft. deep, into which settled raw sewage was introduced. The ponds were usually connected in series. Design capacities were in the range of 400 to 700 persons per acre (25 to 50 lb. BOD per acre-ft.). Detention periods were of the order of 20 to 30 days.

While the idea of oxidation ponds is not new, recent developments have tended to make them more advantageous in military installations. The introduction of the modern bulldozer and other heavy earth-handling equipment into construction practice has made the excavation and the cleaning of large basins more practicable. The required area was available at many posts. In arid regions the recharging of ground water that may be concomitant with sewage treatment in oxidation ponds also constitutes a consideration in connection with their use.

Data were examined from three large posts where oxidation ponds were installed. Two of these were in Texas at army installations—Camp Hood and Camp Barkeley. The third was at a naval station at Shoemaker, California. Exceptionally complete data were available from this plant.

Oxidation Ponds at USNS, Shoemaker, Calif.

The Shoemaker plant consisted of primary settling with separate sludge digestion, oxidation ponds and a final chlorine contact pond.

The overall volume of the oxidation ponds, including the chlorine contact pond, was about 300 acre-feet.

The average per capita flow of sewage was 93 gallons daily; the per capita production of BOD was 0.18 pound daily, of SS 0.19 pound daily. Removal in the primary settling was 63 per cent for SS and 39 per cent for BOD. Efficiency of the oxidation ponds was 43 per cent for SS and 76 per cent for BOD. Removal in the oxidation ponds was 16 per cent for SS and 46 per cent for BOD. Overall removal was 79 per cent for SS and 85 per cent for BOD. SS in oxidation ponds increased during the summer by the growth of algae that imparted an emerald green color to the sewage. At no time, however, were odors of decaying algae noted. Odors at the plant were not particularly objectionable, but were noticeable during certain periods.

Bacterial Efficiency

The ponds had a remarkable ability to remove coliform organisms. Individual samples very often would show no positive presumptive tubes in 10 ml. portions. No chlorine was used during the period reported.

Nitrogen Tests

Ammonia nitrogen averaged 20 to 30 p.p.m. in the primary effluent, while nitrites and nitrates were not present in appreciable concentrations at this

point. Reduction of ammonia in the oxidation ponds was greatest during the summer.

Maintenance of Ponds

No mosquito nuisance developed from the ponds; at the time of visitation, no larvae were found in the littoral regions. Water plant growth was not marked. The surface of the downstream ponds was free from scum, and no evidences of sludge deposits were detected.

ADDENDUM

The Subcommittee has considered several aspects of the problem of sewage treatment plant design and operation in military camps and has adopted the following recommendations:

(1) The design of sewage treatment works for military camps should be handled only by competent firms of sanitary engineers, whose competency should be certified by the design divisions of the Department of Defense. These divisions, aided by an advisory board, might maintain a list of engineers approved for such work.

(2) Patented or proprietary processes of sewage treatment should not be designed unless such processes have been operated and proved efficient in treatment of army camp sewage.

(3) The Subcommittee deplores the loss of good civilian sewage works operators and chemists in World War II by induction into the army and removal from operation of sewage treatment works. A special plea is addressed to future draft officials to recognize this rather rare case of technical skill and to defer such men if they are needed in operation of military sewage treatment works.

(4) When inducted men with sanitary engineering or chemical skill are assigned to sewage works operation, only the most urgent manpower needs should be allowed to result in their transfer. Even with adequate technical training, the time required to train an operator for efficient operation of such plants is considerable and might result in inadequate control of operation for an uncertain period.

Comments by R. S. Rankin *

Mr. Rankin questions whether all results should be given equal weight, claiming the poor results at F. E. Warren (3,700 lb. loading of BOD per acre-ft. and only 50.5 per cent efficiencies of removal) were due to return of poor supernatant and high grease content in raw sewage; also first-stage results at Ft. Sill, with only 0.9 hr. sedimentation instead of 2.0 hours; and a third plant with flooded underdrains. He believes these deficiencies would be corrected in municipal plants.

With reference to efficiencies, Mr. Rankin mentions results from 14 municipal plants, some nine in New Jersey and five others reported by Dreier, in which a straight efficiency of 80 per cent removal of BOD fits the actual data better than removals calculated by the equation used for army camps. Efficiencies appear to remain constant regardless of loading.

A further study was made of municipal results of BOD loading on an area basis (per sq. ft.) rather than per acre-foot, and applying 80 per cent efficiency. Results are shown in Figure 16. The points for fourteen plants fall well along the line of 80 per cent efficiency. This indicates that area applies, within the limits of dosing and depth of filters in the table (6 to 10 ft.).

* Sanitary Engineer, The Dorr Company.

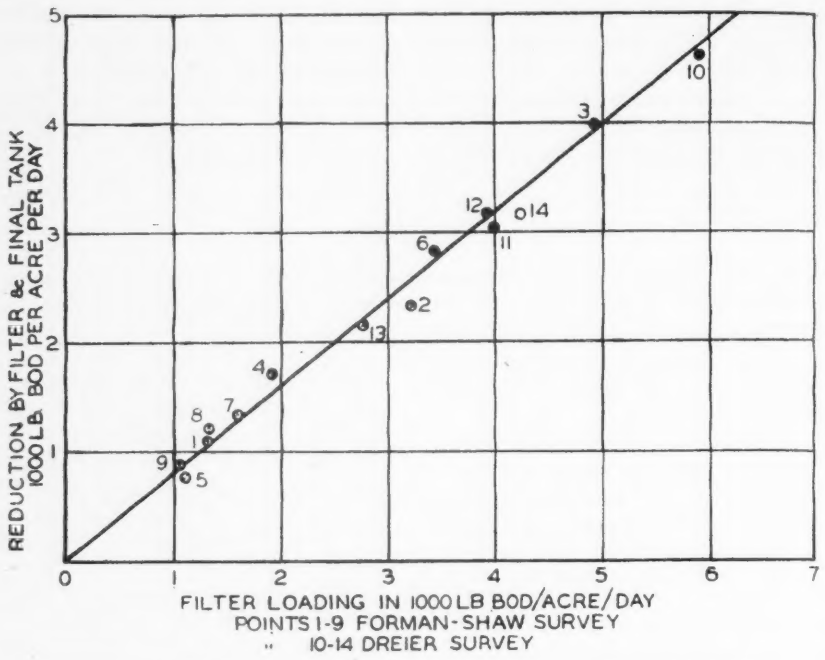

REDUCTION BY FILTER & FINAL TANK
1000 LB. BOD PER ACRE PER DAY
FILTER LOADING IN 1000 LB BOD/ACRE/DAY
POINTS 1-9 FORMAN-SHAW SURVEY
" 10-14 DREIER SURVEY

FIGURE 16.—Relation between loading and performance in low-rate plants—no recirculation.

Similar comparisons are made for the army data, dropping results for Fort F. E. Warren, and increasing Fort Sill efficiency from 63 to 71 per cent.

Walton's studies for the Upper Mississippi Board of nine states resulted in a conclusion, in a statement of policy by sanitary engineers of the nine states, that the BOD removal was a function of applied load per unit of area. The formula derived was $R = 0.66\ L - 0.02$, in which R = BOD reduction in lb. per sq. ft. per day and L = loading in lb. per sq. ft. per day. The removals at these rates averaged 63 per cent. All filters were 6 to 8 ft. deep. Mr. Rankin claims that there is considerable evidence to justify application of the formula to shallower filters.

The need for adequate settling capacity following high-rate filtration is well known. The Walton report concluded that 70 per cent was removed by the filter and 30 per cent by the settling tank. It would be of interest to know how these relative removals apply to the army plants.

Army two-stage filter plants included an intermediate settling tank whereas this is usually omitted in municipal plants.

Mr. Rankin states that "possibly the ultimate 'formula' will be found to be a combination of several methods which will take into account not only efficiency of BOD removal but other factors such as the ammonias and nitrogens."

Other Comments

A few other comments were received, including those by Rolf Eliassen and W. A. Hardenbergh. These comments dealt largely with personnel and procedures in the Corps of Engineers and Sanitary Corps relating to the operation and administration of sewage treatment plants. These topics were covered in the summary report; therefore the discussions are not included here.

Military Liaison With Sub-Committee

Messrs. M. J. Blew and James W. Feild were appointed liaison members of the Subcommittee in February, 1947, by the OCE, to replace Messrs. J. T. Norgaard and Harry Stevens, who had worked with the Subcommittee since its inception. Messrs. Blew and Feild collaborated with the Subcommittee during the last two meetings in the preparation of the summary report.

Industrial Wastes

THE INDUSTRIAL WASTE PROBLEM. IV. BRASS AND COPPER, ELECTROPLATING, AND TEXTILE WASTES *

By William S. Wise

Chief Engineer, State Water Commission, Hartford, Conn.

The three types of industrial wastes discussed here are produced in industries accustomed to a generous use of water. These industries are typical of many in which major changes are taking place in the form of installations of new equipment and new processes. Such changes may in turn alleviate some of the waste treatment problems, aggravate others or create new problems.

From a pollution standpoint the brass and copper and electroplating wastes do not represent any problem of a B.O.D. nature because they contain no bacterial food and require practically no dissolved oxygen for oxidation and stabilization. Actually their ingredients—copper, zinc, nickel, chromium, acids, cyanides, etc.—are of an inorganic nature, are toxic, and they inhibit bacterial growth and decomposition in a receiving stream. The ordinary pollution standards therefore cannot be applied to the effects of these wastes. Textile wastes are somewhat different because they do contain some bacterial food and oxygen consuming material.

The treatment of these wastes must be considered from the standpoint not only of the present conditions but also of the future indications. Evidence seems to point to the initiation of greatly accelerated industrial research work. In all probability the future will witness new products, new equipment, new processes, changes in the character of industrial wastes and new treatment methods. Another indication is that greater emphasis will be placed on the need for conservation of all natural resources including water, and more efforts will be made in this direction.

Brass and Copper Mill Wastes

Origin, Nature and Volume

The water-borne wastes from brass and copper mills result from the production of sheets, tubes, wire and rods rolled or drawn from cast bars or billets. The metallurgical characteristics of these alloys require a certain amount of annealing for fabrication between the original form and finished product. During the cooling of the metal, an oxide scale is formed on the surface which must be removed by acid pickling before further processing, particularly drawing operations.

A considerable reduction in volume of pickling wastes can be expected as mills install modern heavy rolling and drawing equipment and new annealing furnaces operating with reducing atmospheres. A Connecticut plant has recently installed a new sheet rolling mill and a new annealing furnace to replace obsolete equipment. The new equipment will handle more material

* One of a series of special contributions by members of the FSWA Committee on Industrial Wastes.

and will turn out the finished product with two pickling operations, whereas six operations were necessary with the old equipment. The volume of industrial wastes from increased production was thus reduced by about 66 per cent in this particular instance. Due to certain limitations in drawing operations on tubes, rods and wire, modern equipment will not accomplish as great a reduction in volume of wastes produced in the manufacture of these products.

The pickling of strip sheet following the annealing operations is done either in a continuous strip pickling tank, or manually in the form of coils immersed in the pickle. Coils of wire and rods and bundles of tubes are usually immersed manually. The pickle tanks have capacities of from 300 to 1,500 gal. depending upon the type of product. The fresh pickle solutions usually contain about 10 per cent sulfuric acid. The bright dipping solutions used for removing "stains" not removed by the pickle usually consist of about 8 per cent sulfuric acid and 5 per cent sodium dichromate. The length of time the solutions can be used before they become "spent" and dumped varies with the kind of alloy and the amount pickled. Some tanks may be dumped weekly, others monthly, while some are only dumped once or twice per year. After the products are pickled they are rinsed in tanks with a continuous flow of water. The rinsing operations produce most of the industrial wastes and, although dilute, they contain most of the total acid and metals lost. An investigation indicated that 88.5 per cent of the acid and 90 per cent of the metal lost occurs in the rinsing operations. The remainder is lost in the spent pickling and bright dipping solutions.

The nature of the wastes and the great variations are shown in the following summary of analyses made on a large number of hourly composite samples collected at one mill. The results are in parts per million:

	Rolling Mill	Tube Mill	Rod and Wire Mill
Sulfuric acid	140–1997	4–209	192–4942
Copper	10–87	34–147	385–1582
Zinc	28–112	19–73	350–4300
Chromium, hexavalent (Cr^6)	0–35	0–5	0–67
Chromium, total	6–84	3–78	345–1100
Iron	1–13	1–5	9–93

The volume of water used and discharged as industrial wastes varies greatly among the various mills. At one typical plant producing about 450 tons per day of sheet, rods, wire and tubes, the volume of wastes was estimated at about 1,000,000 gal. per day. Another plant of similar size was found to use about three times this volume.

Treatment of Wastes

The treatment is essentially a neutralization and precipitation process. When bright dipping with sodium dichromate is used the chromium is present in both the hexavalent (Cr^6) and trivalent (Cr^3) forms. The hexavalent form will not precipitate upon neutralization and it must therefore first be reduced to the trivalent form. This is best done with sulfur dioxide.

A pilot plant has been operated recently at a mill where a portion of the wastes from one pickling and rinsing unit was treated by the following steps: (1) equalization; (2) reduction of hexavalent chromium with sulfur dioxide; (3) neutralization with lime

in a flash mixer; (4) flocculation; (5) precipitation in a clarifier; (6) sludge dewatering on a vacuum filter.

Two kinds of lime were used in slurry form: (a) high-calcium hydrated, and (b) high-magnesium quicklime. Economic advantages were found in the use of the high-magnesium quicklime form. The addition of lime was automatically controlled by a pH recorder with its electrode placed in the flash mixer where a pH of about 8.0 was maintained.

The best clarification was obtained by flowing directly from the flash mixer to the clarifier, indicating that flocculation was of no advantage. An average detention period of 6 hours and an overflow rate of 100 gal. per sq. ft. per day was found necessary. Excellent results were obtained by dewatering the sludge on a vacuum filter. Sludge containing 0.13 lb. per gal. at 17° C. (1.5 per cent solids) was dewatered at a rate of 7.0 gal. per sq. ft. per hr. and the cake had a moisture content of about 85 per cent. The clarifier effluent was clear, free from metals and had a pH of about 7.5.

Ion-Exchange

As an alternate procedure an attempt was made to concentrate the waste to a strength suitable for recovery in an electrolytic cell by use of the ion-exchange principle in synthetic resin beds. The original plan was to remove Cu, Zn and Cr^3 in a cation bed and Cr^6 in an anion bed.

It was found, however, that the Cr^6 was reduced to Cr^3 by the cation resin when the pH was less than 6 and the anion bed was of no use. Furthermore, the reduction had a detrimental effect upon the cation resin. To prevent this the Cr^6 must first be reduced by SO_2 before being applied to the cation bed.

The effluent from this bed, when regenerated with Na_2SO_4, is slightly acid, contains less than 1 p.p.m. of Cu and Zn and about 30 per cent of the entering Cr. The bed could be regenerated more cheaply with sulfuric acid. The effluent in this case would be much more acidic and would contain about twice as much Cr. Nevertheless, it may be economically justified.

About 50 gal. of waste could be passed through a bed of 0.25 cu. ft. of resin at the rate of 2 g.p.m. per cu. ft. of resin before a break-through. The regenerant from such a bed can probably be concentrated by various means to about 2,000 p.p.m. Cu, 2,000 p.p.m. Zn and 700 p.p.m. Cr. These concentrations are not as high as was anticipated for a good recovery process.

The difference in the per cent of chromium to copper removed by the sodium and the hydrogen regenerated beds indicated a possibility of partial separation and further concentration by repeated passes. Until the details of such a process are worked out, however, the ion-exchange process will have a less favorable application than chemical precipitation.

Recovery of Metals

Studies have indicated that the losses amount to about 3,000 lb. sulfuric acid, 650 lb. copper, 700 lb. zinc and 350 lb. chromium per 1,000,000 gal. of wastes. An effort to recover the metals therefore seems justified, and research work has indicated that the following steps are feasible: (1) mixing of soda ash with dewatered sludge; (2) roasting the mixture in a furnace and oxidizing the trivalent chromium to hexavalent form; (3) extraction of sodium chromate for re-use; (4) dissolving the residue in spent acid pickle and sulfuric acid; (5) deposition of copper on brass chips for re-use or resale; (6) recovery of zinc in an electrolytic cell as electrolytic zinc, the sulfuric acid being returned for dissolving residue in (4).

While no figures are available on the cost of the treatment and recovery processes, it appears promising to recover the metals at a cost whereby the net value will pay for a portion of the treatment cost.

Electroplating Wastes

Origin, Nature and Volume

Metal plating is essentially an electrochemical process whereby a base metal, such as steel or brass, is coated with a tightly adherent metal for protection against corrosion, or for decorative appeal, or to obtain certain physical or chemical characteristics. The most common metals used for plating are copper, nickel, chromium, cadmium, zinc, brass, tin and the precious metals, silver and gold.

Before plating the surface of the base metal must be free from any corrosion products and must be chemically clean. If rust or other corrosion products are present they are removed by acid pickling or bright dipping processes. The removal of oil and other substances is carried out by immersion in hot alkaline cleaning solutions, with or without electric current; rinsing in hot or cold water; dipping in weak acid and final rinsing. Certain articles are further dipped in a cyanide solution and rinsed before going to the plating baths.

Some articles are plated with three or more metals in separate baths; others receive only one coating according to requirements. Cold rinses are used following each bath and finally some are rinsed in hot water for quick drying. The waste originates from the rinses and spent plating solutions.

Plating solutions containing cyanide are strongly alkaline—pH 9 to 12 (copper, zinc, brass, cadmium, silver). Others are strongly acid—pH 1 to 5 (nickel, chromium, certain zinc, anodizing, pickling, etc.). The composition of the wastes depends upon a number of factors: the kind of plating, manual operations or automatic plating machines, stationary or continuous flow first-rinse tanks, amount of water used in various rinses, period of time plating solutions are used before dumping, filtration of baths for longer use, and the care exercised in operation of the plating room and plating operations.

Analyses of composite samples of wastes from different plants showed the following composition (results in p.p.m.):

Plant	pH	Copper	Nickel	Total Chromium	Iron	Cyanide
A	3.2	16	0	1.0	10.8	6.4
	10.4	19	0	0.5	3.0	13.6
	1.7	58	2	0	31	57
B	1.9	—	40	112	—	0.2
	1.8	—	88	27	—	0.4
C	9.6	88	205	0	—	18
	4.4	15	10	430	—	9
	1.5	52	20	2700	—	4
	2.2	18	5	229	1.6	6
D	3.5	6.4	37	21	1.5	7.6
	4.1	7.4	25	11	1.5	7.4
	10.7	14	19	39	3.5	2.0

No figures are available correlating the volume of wastes with the amount of material plated, a most difficult figure to obtain. The volumes produced in the above plants (vastly different in size and equipment) have been esti-

mated as follows: A—40,000 g.p.d.; B—2,000 g.p.d.; C—200,000 g.p.d.; D—25,000 g.p.d.

Treatment of Wastes

Two methods of treatment are in use in Connecticut, *i.e.*, chemical precipitation on batch basis, and lagoons. Chemical treatment at Plant C above consists of the addition of ferrous sulfate and lime when the concentration of chromium is less than 200 p.p.m. When the chromium exceeds this figure barium sulfide and lime are used. The settling period is 4 hours or more and the sludge, amounting to from 2 to 5 per cent, is hauled away. The effluent is comparatively free from metals and has a pH of around 8. The cyanide is reduced by 60 to 70 per cent.

Lagoon treatment at Plant A above consists of two baffled lagoons operated in series with a detention period of 4 days. These lagoons receive the acid wastes containing cyanide and metals. A portion of the cyanides volatilize as hydrocyanic acid gas, and a portion is converted to cyanates. The effluent from these lagoons is mixed with about an equal volume of alkaline wastes from another drain and flows into a third baffled lagoon with a detention period of about one day. This treatment reduces the copper content about 60 per cent and the cyanide 85 per cent. The pH of the effluent is about 6.

Sludge disposal is a problem encountered in all industrial waste treatment by chemical precipitation, especially in plants with insufficient area for sludge drying beds. However, the encouraging results obtained in dewatering sludge on a vacuum filter from brass and copper waste treatment indicates a possible solution in the large electroplating plants.

Treatment of plating wastes from a large plant have been described by Barnes (1) where ferrous sulfate and lime are used for precipitation followed by chlorination to destroy the remaining cyanide. Dobson (2) has also described the treatment of cyanide wastes by chlorination. He finds that about 7 parts of chlorine are required per part of cyanide and the reaction must take place in an alkaline solution with pH above 8.5.

Textile Wastes

Origin, Nature and Volume

These wastes originate from the dyeing and finishing of textile materials, principally cotton, wool, rayon and silk. In the manufacture of some types of cotton cloth a sizing treatment (usually starch, gelatine, soaps and oils, etc.) is given the yarn to aid in weaving. Before the cloth can be dyed the sizing must be removed. This is usually done in a hot caustic soda boil or in a malt diatase solution or similar substance. Some cotton cloth is given a kier treatment to remove natural fats and waxes, grease, etc., prior to dyeing or printing. The kier treatment involves boiling for several hours in a caustic soda-soda ash solution. It is then bleached either in a hypochlorite or a sodium peroxide solution. A considerable amount of cloth is given a luster finish (known as mercerizing) in concentrated caustic soda, followed by rinsing and souring in weak sulfuric acid. Wastes from dyeing operations consist of spent dye solutions, together with a number of rinses.

Raw wool usually contains from 15 to 30 per cent of grease, dirt, etc., and is therefore "scoured" before it is spun into yarn. The scouring is usually carried on in a series of "scouring bowls" containing hot solutions of soap, soda ash and water followed by rinsing processes. These wastes are the most objectionable of all textile wastes. Most weaving and dyeing plants purchase wool already

scoured. Spinning and weaving require that a small amount of grease remain on the fibers, which in some cases must be removed prior to dyeing. During the later finishing processes certain oils are added to the soap solutions and rinses to give the cloth a soft texture. In some cases the yarn is dyed before weaving; in others the cloth is dyed after weaving.

Variations in character of composite samples collected from various plants are as follows (results in p.p.m.):

Plant	pH	Total Solids	Volatile Solids	Suspended Solids	Oxygen Consumed	5-day B.O.D.	Fats and Greases
Cotton Wastes							
A	11.4	1928	408	8	450	153	60
B	11.5	3172	1490	26	1210	—	30
Woolen Wastes							
C	8.85	1584	590	264	822	282	—
D	8.70	5514	1236	868	1802	520	—
E	9.85	2372	436	118	666	282	—
F	9.35	4200	1100	120	1220	460	220
Rayon Wastes							
G	7.0	2196	509	276	1068	752	—
H	7.5	6130	478	158	409	299	—
Rayon and Wool Wastes							
I	7.0	710	278	143	284	253	—
J	8.2	1540	324	112	240	220	—

Some of the above variations are due to changes in manufacturing processes.

The volumes are also difficult to obtain and are quite variable. Figures ranging from 15,000 gal. to 35,000 gal. per 1,000 yards of cloth have been measured and estimated.

Treatment

The treatment of these wastes is usually a chemical precipitation process. For cotton wastes a combination of two or more of the following chemicals was found most effective: sulfuric acid, ferrous sulfate or "Ferrisul," alum, lime, and calcium chloride. Reductions of about 60 per cent in oxygen consumed and color were found with proper chemical combinations to suit the individual wastes. Further treatment on a trickling filter at a rate of about 400,000 gal. per acre per day produced an additional 25 per cent reduction.

The following treatment results have been obtained on woolen wastes: Plant C—2 lb. alum and 2 lb. sulfuric acid per 1,000 gal. reduced the oxygen consumed by 85 per cent and suspended solids by 95 per cent; Plant D—the same amounts of chemicals resulted in 90 per cent oxygen consumed reduction and 98 per cent in suspended solids.

Rayon wastes treated with about 3.5 lb. ferrous sulfate and 2 lb. lime per 1,000 gal. reduced the oxygen consumed by 60 per cent and suspended solids 90 per cent. The addition of 3 lb. alum and 1.5 lb. chlorinated lime, or 3 lb. ferrous sulfate and 1 lb. lime

per 1,000 gal. of rayon and woolen wastes, causes a reduction of 90 per cent in oxygen consumed and 95 per cent in suspended solids.

In all of these treatments a settling time of about 3 hours is necessary and the volume of sludge ranges from 8 to 15 per cent.

Discussion

The object of this discussion is merely to present a general picture of the wastes from these three types of industries and to outline present methods of treatment. Many details, important factors and encountered difficulties were omitted in the interest of brevity. No lengthy discussion is necessary to support the contention that each industrial waste treatment problem is an individual one because of the combination of many factors which control or affect the solution. The most important consideration in pollution abatement is the size and character of the receiving stream in relation to the volume of wastes and the quality of the water that is required for the stream's subsequent use.

Industries and industrial processes change, some rapidly and others more slowly. Industrial waste treatment plants therefore cannot be designed for an expected life as great as is customary for the design of sewage treatment plants. It is necessary to incorporate as much flexibility as possible into the plant as the individual conditions appear to warrant.

Obviously, industrial waste treatment problems do not lend themselves to handbook solution.

References

1. Barnes, George E., "Treatment Works for Plating Wastes Containing Toxic Metals and Cyanides." Presented at Third Industrial Waste Conference, Purdue University, Lafayette, Ind., May 22, 1947.
2. Dobson, Joch C., "The Treatment of Cyanide Waste by Chlorination." THIS JOURNAL, **19**, 6 (November, 1947).

THE OPERATOR'S CORNER

CONDUCTED BY S. C. MARTIN

PUBLIC RELATIONS AND POLITICS

The November municipal elections again have come and gone. In their wake are some reports of probable turnovers in sewage works staffs as a result of administration changes. Although each year marks a decline in the number of municipal utilities so earmarked for political spoil, even one such instance shames community complacency.

A case in point is that of a well-known midwestern city where a decade of responsible, efficient, nonpolitical sewage works administration may be abruptly terminated by the "outs" who have become the "ins." Built since the last city hall upheaval, the sewage works have been administered by a carefully gathered staff whose professional capabilities are unchallenged. Yet these professional men are now threatened with the indignity of unjustifiable dismissal, openly flaunted in the newspapers. If events follow the course of current indications, many years of conscientious service will be sacrificed to political authority and municipal indifference. Meanwhile, organization morale is shattered.

Politicians are supersensitive to public opinion; they are allergic to situations that leave them in a bad position before the eyes of the electorate. Here may be the key to the solution of the problem.

Through well-conceived and properly executed public relations activity, sewage works administrators can develop the type of public support the politician will respect. When the public is properly informed, it will not tolerate political tampering with the supply lines of municipal service.

Three things are required of every sewage works man who would win the support of his public: a job well done; service free from the taint of partisanship or politics; a positive program for developing public appreciation of efficient stewardship. An administrative program which ignores any one of these essentials will be as unstable as a two-legged stool.

Perhaps some sewage works men have only themselves to blame when they are subjected to political pressure. Their zealous devotion to plant operation rather than to public education, their abhorrence of mechanical inefficiency rather than community indifference, their preoccupation with the present rather than the future point to a limited understanding of their responsibilities. Of what long-term value is even a decade of faithful sewage works administration if it is followed by a long period of substandard leadership and constant political meddling? Sewage works are constructed to stand for a generation; they should be administered with the same perspective!

Sewage works men have a service to *sell* as well as a duty to perform. In doing so they must serve the public with impartial courtesy and a genuine display of personal interest in individual problems. They must meet the public as friendly neighbors, rather than as government functionaries. They must inform and interest the

public in the value of sanitary protection to the community and the quality and efficiency with which this is provided. Public opinion thus developed will constitute a bulwark of appreciation and good will which will stand against all political maneuvering.

Basically, a public relations program is a program of friendship, and friendship is a two-way street. Continuity of sewage works administration is as much a dividend from community friendship as it is a reward for faithful service.

S. C. M.

SEWER MAINTENANCE EXPERIENCE AT LONG BEACH, CALIF.*

By D. R. Kennedy

Sewer Maintenance Engineer, Long Beach, Calif.

The matter of sewer maintenance is one which covers such a variety of subjects that it would be difficult to select any one item for discussion at a meeting of this kind. Almost anything pertaining to this important problem, however, is interesting to those who are responsible for the proper functioning of a modern sewer system. Accordingly, this discussion will be devoted largely to the problem of sulfide control, which has been of general concern in Southern California.

At a meeting of the Arizona Sewage and Water Works Association held in Yuma, Ariz., several years ago, Mr. A. M. Rawn, chief engineer of Los Angeles County Sanitation Districts, invited the author to discuss informally the problems of sewer maintenance. In his introductory remarks Mr. Rawn said that Long Beach, the city the author represents, probably had the "dirtiest" sewers of any city in Southern California. Although these remarks were made jokingly, nevertheless they soaked in and brought home the realization that the maintenance of a sewer system is vitally necessary if satisfactory operating results are to be expected. As an old construction man, the author was not particularly concerned with the future of a sewer job, but like many others was interested primarily in getting the job finished, cleaned up, accepted, and the next one started.

General Maintenance Practices

It had been the practice in Long Beach to clean sewer lines only if they became so badly fouled as to interfere with the flow. If they became plugged as a result of the introduction of debris or other foreign matter, a crew was sent out equipped with a stack of jointed wooden rods to remove the offending obstruction. This operation was not as simple as it would appear from the above. Getting the rods into the line was frequently a job that required considerable manipulation and skill on the part of the operator, particularly if the manholes were "loaded"—which was generally the case.

The adventure of a member of our maintenance crew who was sent out to remove a stoppage is very vividly remembered. The obstruction was obstinate and could not be budged from

* Presented in the Operators' Forum, 20th Annual Meeting, Federation of Sewage Works Associations; San Francisco, Calif.; July 21–24, 1947.

the lower manhole, so this man undertook to handle it from the upper end. There appeared to be about 2½ ft. of accumulated sewage in the upper manhole, into which he plunged with an armful of rods. By the time he had completed his job, the level of the sewage had reached his neck, and it was indeed a bedraggled individual who emerged from the manhole.

About the time the "Flexible" sewer rod was developed, the city bought a set, one of the first to be sold. The tools did a good job so far as the removal of stoppages and roots was concerned, but there was still something lacking; the job of adequately cleaning lines remained a problem.

In the meantime, the earthquake of 1933 disclosed a very serious condition in the sewers in certain areas, particularly where concrete pipe had been used. In many cases lines had disintegrated to the point of failure, and, in the years following, replacement was undertaken and is still under way.

In an effort to prolong the life of such lines as were not in danger of immediate collapse, chlorination was suggested. Chlorinators were installed at strategic points and chlorine applied in varying dosages. It was not the idea to use chlorine as a cleansing agent or for sterilization of the flow, but rather to control the formation of sulfides which, fundamentally, were the cause of the difficulty. Perhaps the life of the concrete pipe was lengthened as a result of these experiments, but it was soon evident that other measures must be taken to prevent, if possible, the formation of sulfide generating bacteria.

About this time—about 1934—something radically new in the treatment of sewage, and particularly in the control of sulfides, came to light. This method, which was exploited enthusiastically, involved the utilization of a highly concentrated oxygen (ozone) produced electrically. Undoubtedly this product had possibilities; at least it appeared to serve the purpose of a masking agent, and it did clear the atmosphere. The process consisted of forcing the ozone into wet wells, force mains, or even into the atmosphere, but without regard to quantity, if such could be determined. This new treatment was tried in Orange County, but without success.

The Sanitation Districts of Los Angeles County had achieved considerable success with the use of a soft rubber beach ball for cleaning sewer lines, and in desperation it was decided to try this in Long Beach. Certainly the Sanitation Districts were doing an excellent job, and it was logical that if such a plan would work for them it would do likewise for Long Beach. The results obtained were far beyond expectations. It was amazing to witness the quantity and character of the material disgorged. Some difficulty was encountered, especially as a result of punctures and cuts. In order to protect them, the balls were wrapped with burlap or enclosed in canvas bags. While these precautionary means served as a measure of protection, they were not the answer. Eventually a member of the department developed a sewer cleaning ball which, it is believed, is a great improvement. This will be described later.

Cloroben Experiments

Several years ago the neighboring city of Los Angeles was in trouble, not alone with the sewer system but with the treatment plant as well. Reuben Brown, superintendent of sewer maintenance, became convinced as to the possibilities of Cloroben for sulfide control and as a result the city of Los Angeles undertook to test it. The results of this work were not made available until the experiment had been carried on for several months. The findings appeared remarkable, at

least to those who had been floundering around trying to solve the intricacies of sulfide control. Much had been written on this subject and many theories advanced as to suitable measures of control, but it seemed from the reports of Mr. Brown that Cloroben had solved the problem.

Apparently Mr. Brown is an advocate of the exchange of courtesies and ideas, either within an association or between individuals. When he was asked for an opinion and advice concerning the use of Cloroben at Long Beach he responded generously and gave the results of his experiments and observations. In fact, he gave such a glowing account of his results at Los Angeles that Cloroben was recommended for use at Long Beach. This action has never been regretted.

The city of Long Beach is under contract with the Sanitation Districts of Los Angeles County to discharge the flow from a highly developed residential area, in the northern part of the city, into the facilities of the Districts. To accomplish this it is necessary to pump from a central pumping station through a 21-in. R. C. force main a distance of 4,300 feet. The regulations of the Districts require that the dissolved sulfides not exceed 0.5 p.p.m., and with concentrations averaging 3.25 p.p.m. it was essential that some type of treatment be provided.

A chlorinator was installed and dosages of 12.0 to 15.0 p.p.m. in summer and 3.0 to 6.0 p.p.m. during winter months recommended. Even with such heavy dosages of chlorine it was difficult to meet the requirement of the Districts. With a dosage of 12.0 p.p.m., the sulfides were reduced to 1.0 to 1.5 p.p.m., and with 18.0 p.p.m. of chlorine, to 0.5 p.p.m. dissolved sulfides. The cost of chlorine averaged $12.00 per day for this installation.

Following the experience at Los Angeles, it was decided to discontinue the use of chlorine and try Cloroben instead. Having available the results of the experiments of Mr. Brown and his staff, a plan was worked out which was believed would be satisfactory. A dosing station was set up at some distance from the pump station, the idea being to provide as much contact time as possible. A flash dose of Cloroben was applied which served to make a substantial reduction in the bacterial count. This was followed by continuous dosages of 1.0 p.p.m. From the beginning the sulfides appeared to be well under control and have continued so for over a year.

During this period an intensive cleaning campaign was undertaken and the Cloroben treatment discontinued for a full month, with only a slight increase in sulfides. Upon resumption of treatment, and with the same Cloroben dosage, viz. 1.0 p.p.m., no material change was noted. Treatment has been continued to date and while the dissolved sulfides are slightly above the allowable concentration, the discharge has been acceptable to the Districts.

A very substantial saving was effected at this station by the substitution of Cloroben for chlorine, and the surplus of the funds budgeted has been used for experimental purposes and the treatment of other areas where difficulty has been experienced.

Discussion of Results

The results obtained in later experiments were fair but very erratic, and control of sulfides was difficult. In each case now under consideration, long force mains are utilized and these undoubtedly are a factor in providing seeding places for the generation and propagation of sulfides. The results obtained in these areas are not altogether satisfactory but this may be attributed to a lack of proper contact time.

This factor of contact time is highly

important and it has been found that in order to obtain anything like satisfactory results sufficient contact time must be provided. Just what this time should be has not been definitely established, nor has such information been made available by the manufacturer.

From observation it has been found that a contact period of not less than 2½ to 3 hr. appears to give the best results. Where such contact time is limited to a matter of minutes, as is the case in at least two installations, the dosage applied must of necessity be increased or applied directly to the pump pit. Obviously, such practice is not recommended for several reasons, principal of which is that while the slimes may be temporarily removed from the pressure line, the sewer system derives no benefit whatever.

It has been definitely established that such dosages as are applied to the wet well are effective only for a matter of a few days following the introduction of the Cloroben. This was tried in Long Beach slightly over a year ago when a flash dose of Cloroben was applied to the wet well and resulted in the reduction of sulfides from 2.0 p.p.m. to 1.0 p.p.m., which concentration built up to 2.0 p.p.m. in 4 days. Following this, a dosage of 1.5 p.p.m. was responsible for the reduction from 2.0 p.p.m. to 0.3 p.p.m., which concentration continued for 10 days when it immediately increased to 5.0 p.p.m., then to 7.5 p.p.m., and finally reached a maximum of 11.25 p.p.m. in 5 weeks.

Following this experience, a reduction in dosage quantity and a change in location of dosing stations was suggested, and arrangements were made to proceed along the suggested plan. A dosage of 1.5 p.p.m was applied with the result that the reduction from 8.0 p.p.m to 1.4 p.p.m. was reflected within 24 hours. This varied from day to day, gradually taking an upward swing from 2.5 to 5.0 p.p.m. and continuing a generally erratic

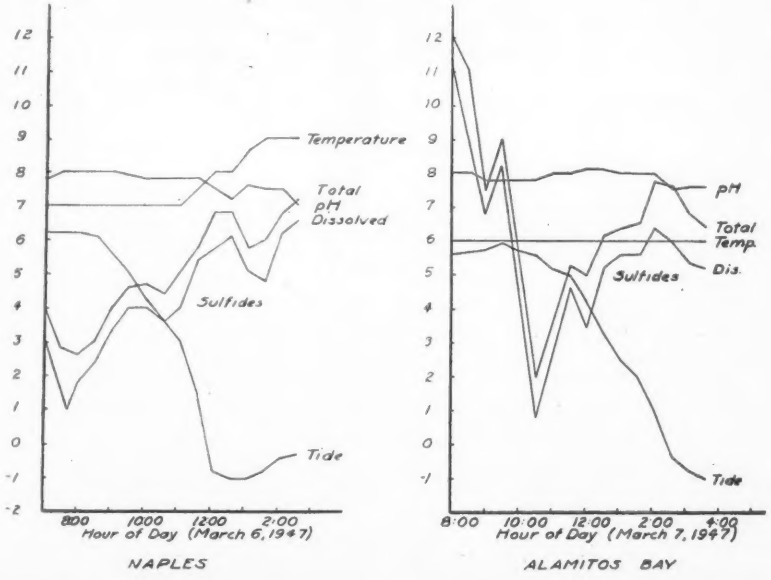


FIGURE 1.—Observed sulfide, temperature, and pH values, and tidal movement.

course. Because of the low-lying area in which this part of the system is located, all of which is subject to tidal movement, it was believed that high tide may have had some bearing upon the seemingly uncontrollable action of the sulfides. A tide curve was plotted on certain of the observed sulfide readings, but there was no apparent connection between the two, and the idea was abandoned. Figure 1 will serve to clarify the above statement.

Figure 2 represents typical half-hour readings over the period 8 A.M. to 3 P.M., and Figure 3 represents a daily record of readings covering the months of April and May, 1947. The readings shown also represent the average daily concentration and are not to be construed as other than average conditions.

During the past several months a series of tests has been carried out for the express purpose of ascertaining if any inexpensive method for the control of sulfides is available. The first test, carried on over a period of 14 days, consisted of: (1) cleaning the force main thoroughly with a ball, (2) applying chlorine at the rate of 5.0 p.p.m.

While a full report cannot yet be made as to the outcome of this test, preliminary observations indicate that the sulfides remained at zero and did not increase for the full period.

Following this experiment, when indications were that sulfides were on the upward trend, the line was again cleaned in the same manner as before and flow permitted to continue without treatment. The third trial consisted of again cleaning the line and applying Cloroben at the rate of 1.0 p.p.m. Complete results of this test are not yet available for the reason that there has not been any increase in sulfides to date. Data on these tests and on any other phases of the work done will be provided to any who may be interested.

Other Sulfide Control Methods

Within recent years a new process for the control of sulfides, particularly in long force mains, has been developed. This consists of the introduction of compressed air into the line during pumping periods. Just how much air is introduced into the flow has not been definitely fixed as yet, but apparently the results so far have been very satisfactory.

One item that should be mentioned is the condition of certain manholes on

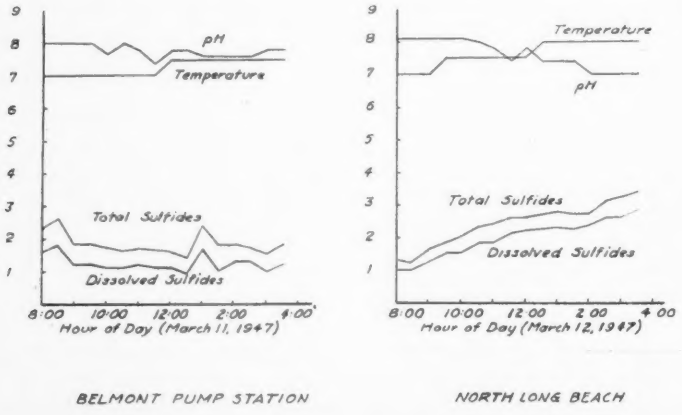


FIGURE 2.—Observed sulfide, temperature, and pH values for a typical day.

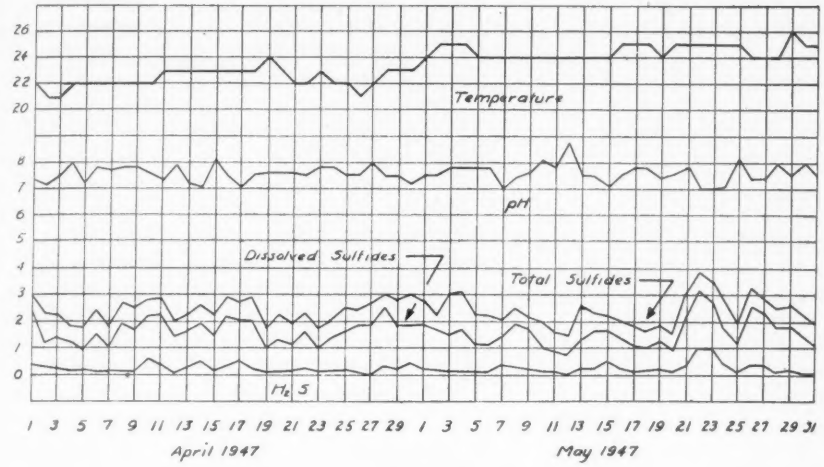


FIGURE 3.—Average daily concentrations of sulfides for April and May, 1947, North Long Beach, Calif.

the Long Beach system. In the past many of these, particularly those in which the sulfide concentration was high, were in danger of collapse because of the swelling of the mortar and consequent spalling of the brick. In one instance of a manhole that was in exceptionally bad shape, it was suggested that the brickwork be neutralized, plastered with cement mortar, and watched carefully. This was done. On a subsequent inspection no further disintegration could be observed and all traces of sweating and moisture had disappeared. This manhole was in a line treated with Cloroben.

Outstanding in the literature on sulfide control is the comprehensive report by Pomeroy and Bowlus. (THIS JOURNAL, **18**, 4, 597 (July, 1946).) Of particular interest was the conclusion of these authors concerning the removal of slimes by mechanical means. Experience at Long Beach clearly indicates that periodic cleaning is an important procedure for the control of sulfides. After having tried various recommended means and devices it has been concluded that thorough cleaning, regularly performed, is the answer.

In a preceding paragraph the development of a new type of sewer cleaning ball by a member of the Long Beach organization was mentioned. The ball referred to has been in use in Long Beach for some time. The results obtained have been excellent and are worthy of more than passing mention.

The ball is scientifically designed and constructed of specially compounded rubber, the thickness varying with the diameter. Lugs are moulded into the ball to facilitate the attachment of a tag line, and the surface of the ball is equipped with diagonal ribs providing a squeegee effect. On a recent test the ball was placed in a 12-in. line and during its movement along some 440 ft. thereof removed, by actual measurement, over three cu. yd. of muck in 32 minutes. Runs of 3,500 ft. are not unusual, and in some instances as much as three miles of line have been "balled" in the course of an eight-hour day.

An Unusual Problem

The city of Long Beach is situated in an area bounded on the south by the Pacific Ocean and on the north, east, and west by highly productive oil fields. In addition, refineries and processing plants are located near-by. During the war, with its insatiable demand for high octane gasoline, the petroleum industry was taxed to the limit to provide the necessary fuel for our military and civilian requirements.

In addition to the production of oil within the city, practically all of the major companies whose development necessitates the transportation of oil, gasoline, etc. to the harbor area are required to maintain a system of transmission lines into and through the city. As an example of what such a system means, one of the Long Beach streets, which happens to be a major highway carrying a large proportion of the ship yard traffic, has no less than 24 pipe lines located therein. These are owned and operated by several different companies and carry petroleum products of various kinds, including gasoline, wet gas, dry gas, crude, fuel and other oils, and waste emulsion. All of these lines are in addition to the city's gas and water lines.

In spite of close supervision breaks do occur occasionally and oil or some other commodity enters storm drains or sanitary sewers, much to the embarrassment of all concerned, particularly the sewer department.

In January, 1945 during the peak of the war effort, the sewer department was advised by an irate citizen that gas odors were noticed at his residence. Shortly afterward a call was received from a contractor to the effect that he was unable to make a house connection because of the heavy concentration of gas in the sewer. About this time gas odors were picked up at the pumping plant which cares for the sewage flow in this particular section of the city.

Investigation and a series of explosimeter tests reflected a very high explosive value throughout the length of the main trunk line, a distance of approximately 3½ mi., with lesser concentrations in the branches. Samples were taken from the sewage flow and sent to the city laboratory where analysis proved the samples contained either gasoline or kerosene, or both.

Two oil companies were operating in the district whose lines carried either of the commodities designated by the laboratory. These companies were notified. Both reported "no leaks," after having subjected their lines to over-pressure tests. As a result of this information many theories were advanced concerning the cause of the difficulty. In the meantime it became necessary to flush the lines with air to reduce the concentration to the greatest extent possible and thus forestall a potential explosion. Air flushing was accomplished by an air ejector installed at the pump station and operated continuously for several days, in fact until the trouble had been located.

During all of this time an intensive search had been made to determine the source of the gasoline which had entered the system, for it had been definitely established that the material was gasoline, of the casing-head variety. So far little progress had been made, only two gasoline lines had been located in the immediate vicinity; there was no leak in one, the other contained a colored gas, the coloring of which definitely was not soluble in water. Continuous explosimeter tests were taken which indicated little, if any, diminution of the gas concentration except at the pump station where by virtue of the operation of the air ejector the air was reasonably clear.

A complete check of all manholes was undertaken by the sewer department, which, considering that there are some 750 such structures involved, was

somewhat of a job in itself. After several days' search, the leak was finally located. The offender was one of the refineries located a short distance from one of the city sewers.

This refinery has a series of pipelines carrying various petroleum commodities, including casing-head gasoline. The leak was found to be just a pinhole. How such a volume of gasoline could be discharged without being detected at the plant or without showing up in the applied tests is one of those questions not easily answered. It was fortunate indeed that the whole system was not blown sky-high.

Conclusion

The importance of proper sewer maintenance should be stressed. It is a job deserving of much more consideration than it usually receives. This is particularly true in the smaller communities where little, if any, attention is given to sewer maintenance other than removing stoppages when they occur.

A properly equipped maintenance crew is essential to the proper functioning of a modern sewer system. The cost of such a crew will be returned many fold in increased operating efficiency and in the many years added to the life of a sewer system. It seems to be general practice to use the finest obtainable material in the construction of sewers, then promptly to ignore them until trouble strikes. Until a few years ago Long Beach was no exception. Personal observation indicates there are still many cities and towns which are neglecting their sewer systems and which may well profit from the experiences of others.

DISCUSSION BY EWALD M. LEMCKE*

The paper to be discussed is typical of the man who gave it, for it contains some dry wit, some humor, and serious conclusions as to the economy of proper maintenance of sewer systems.

Mr. Kennedy has just discussed maintenance problems relating to the "dirtiest" sewers in Southern California. Much of this discussion will pertain to some maintenance problems regarding the "greatest sulfide producing" sewers in Southern California.

Tests taken in the early 1930's at the end of the second of two Orange County Joint Outfall force mains, which totaled 4 mi. in length, showed sulfides in very high concentrations. During the following years many experiments and much effort have been expended to reduce these sulfide concentrations.

Briefly, the chemicals and methods used for sulfide control since 1930 are as follows:

1. Chlorine was applied in 1928 upon the recommendation of R. F. Goudey, and is still being used.

2. Ozone was tried in 1935 and used for a short period. It was expensive and did not give satisfactory results.

3. Ferrous sulfate, in the form of copperas was used in 1939. It gave fair results in strong sewage but was difficult in application.

4. Lime was applied in 1939, with a feeder for pH control, with little results.

5. Ferrous chloride, as produced by the Scott-Darcey process, has been applied since 1939. It has given good results in strong sewage with high sulfide content but has been expensive in application and maintenance.

6. Zinc sulfate was used in 1942, with fair results when applied in strong sewage and good results in weak sewage. It is still used in a lateral line.

7. Chloroben, tried in 1942 and again in 1947, gave little results in strong sewage.

* Maintenance Engineer, Orange County Joint Outfall Sewer, Anaheim, Calif.

8. Compressed air in a force main was first used in 1942. The results are discussed later.

9. Tri-chloro-phenol was tried experimentally in 1946 with fair results as a sulfide control; it had excellent masking qualities but phenol has been very difficult to secure, so no further tests are contemplated at the present. This work was done on the recommendation of Richard Pomeroy, technical consultant for the Joint Outfall Sewer.

10. Sodium nitrate applied in 1946 with strong cannery waste gave good results but was too expensive for the required dosage.

11. Lime used in 1946 and 1947 gave good results.

After having tried all of the above, chlorine and/or lime now is being used in gravity flowing sewers, and compressed air in force mains for the most effective and economical means of controlling sulfides.

The causes of sulfide development are so ably stated in the Pomeroy and Bowlus paper, THIS JOURNAL, **18**, 4, 597 (July, 1946), that no repetition here is necessary. It is believed that the activity of sulfide-splitting bacteria varies at least in proportion to the B.O.D. of the sewage, because during the summer months the B.O.D. in the Orange County Joint Outfall sewers often exceeds 1,000 p.p.m., and consequently adequate control of sulfides is difficult.

Late in 1942 compressed air was tried in a 16-in. force main, 2.0 mi. long, as an experiment for sulfide control. An 80 c.f.m. compressor was connected to the discharge line about 10 ft. from the pump. As the air arrived at the end of the force main the dissolved sulfides raised from 7.0 p.p.m. to 18.0 p.p.m., and the settleable solids

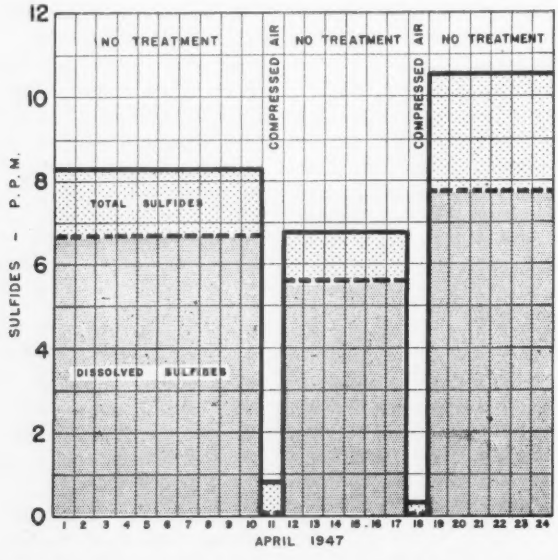


FIGURE 1.—Results of experimental sulfide control in Orangethorpe Avenue force main, showing sulfides during compressed air tests on 2.00-mile, 16-in. R.C. force main. Static head on line was 60 feet. An 80 c.f.m. air compressor used at the Magnolia pumping plant.

increased from 20 ml. per liter to 200 ml. per liter, but within three hours the settleable solids reduced to 22 ml. per liter and the dissolved sulfides to 0.2 and 0.3 p.p.m. On the succeeding three days of experiments the sulfides were reduced to 0.0 p.p.m. within 30 min. after the introduction of air. The settleable solids remained normal. This indicated that after the heavy slimes were blown loose from the pipe, sulfides could be controlled with compressed air. After the war, when help was again available, tests were made to confirm the 1942 results and to establish quantitative requirements. It was found that the air requirement varies with the B.O.D. and temperature, but quantitative conclusions have not been obtained. Some of the 1947 test results are shown on Figures 1 and 2.

The use and effect of cholrine are well known, and will not be discussed here.

Lime used as a shock treatment has given excellent results in the control of sulfide development but experiments, again, are not quantitative at the present time. If confirmation of present experiments continues, the results will be published.

This discussion has dealt entirely with experiences in the control of sulfides, because Joint Outfall personnel have been working on the problem for nearly 20 years. No cleaning program has been started to the present time.

From what is heard about clean sewers and from what is known about sulfides, it is apparent that a combination of clean sewers and adequate sulfide control will: (1) lengthen the life of sewers; (2) increase plant efficiency; and (3) reduce the cost of maintenance.

OPEN DISCUSSION

ALVIN A. APPEL, *Assistant Superintendent of Sewer Maintenance, Los Angeles, Calif.* Reference has been made to the experimental work which was started in the city of Los Angeles a couple of years ago, primarily in the reduction of bacteria. We have had very good results in the reduction of

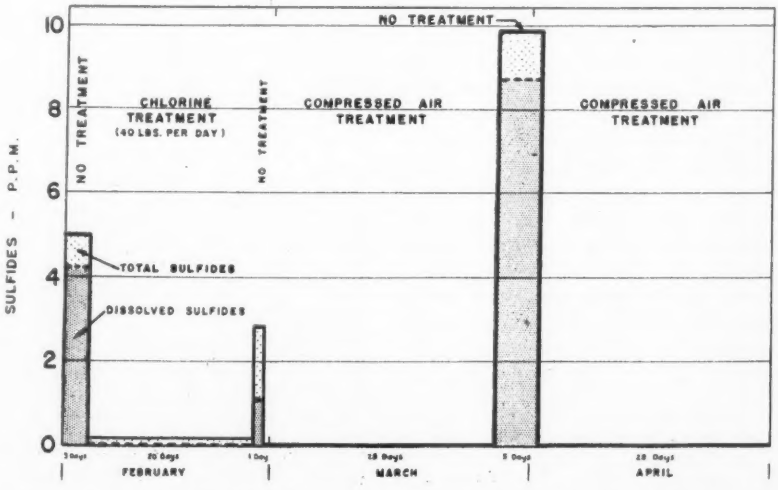


FIGURE 2.—Results of experimental sulfide control in Buena Park force main, showing sulfides during compressed air test on 2.14-mile, 8-in. C.I. force main. Static head on line was 40 feet. A 35 c.f.m. compressor used at the Buena Park pumping plant.

slime and hydrogen sulfide as well as the drying of certain lines and appurtenant structures. To the maintenance division that means considerable intrinsic value. We have also introduced chlorine and make two-week inspections of the outfall. We are making a detailed inspection of the valley line as well as the big 10 by 12-ft. outfall at El Segundo and we are again finding the same drying conditions occurring.

There is something else I should like to bring out and this is something that should be considered by all sewer maintenance men in organization work. Mr. Kennedy mentioned the fact that a good maintenance crew is the heart of all maintenance work. That is a thousand per cent correct. How are you going to get a good maintenance crew? To do so means in-service training, and it means in-service training from the man on the top clear through to the bottom. Now how you can arrive at that is something that must be taken up with your officials in order to get that cooperation. In Los Angeles we are having very fine cooperation from the public officials there and from the leaders of our department and division in permitting us to continue this in-service training work. We are obtaining excellent results from doing this work, which is something to be considered well.

Of course, with in-service training you can raise your standards and specifications for the job that is being requested, as well as work for a better salary. You will be surprised at the results that will be obtained in the way of reduced costs in the organization operation of your sewer maintenance division.

MR. ARTHUR PICKETT, *San Marino, Los Angeles, Calif.* We have had rather unusual experiences in sulfide control, not in sewers, but in storm channels, and particularly in Dominguez slough, which is a major contributor to the pollution in the Los Angeles harbor. That pollution for many years has annually resulted in damage amounting to hundreds of thousands of dollars to harbor installations. The cause of the damage principally is hydrogen sulfide and the blame for years has been placed upon the refineries in County territory.

Two years ago we started working with the refineries to clean up the situation, to get them to eliminate their sulfides. At that time they were giving us from 20 to 80 p.p.m. of sulfides in their waste water. During the past two-year period all the refineries have been placed under our jurisdiction and facilities for the elimination of sulfides have been installed at these plants. Some of the installations have cost as little as $35,000 for one refinery. I don't know what portion of the cost can be attributed to sulfide elimination, but the total cost of changes at one refinery was in excess of half a million dollars. When this work by the refineries was completed the sulfide content of the treated waste discharged to Dominguez Channel was greatly reduced, but sulfides still prevailed in the channel in considerable quantity, with readings as high as 10 p.p.m. per mile.

In trying to find the answer to the problem we have developed the theory that the action of the sulfide-splitting bacteria, on the sulfates in the natural water, is the responsible factor. These bacteria ordinarily exist upon organic or inorganic sludge deposits and get the oxygen they require from this organic material. When the organic material fails to provide enough oxygen they develop the ability to split an oxygen atom from the sulfates present in the natural water, and, as a result, release sulfide which causes the damage. I thought you might be interested in that theory because it il-

lustrates the necessity for keeping sewers clean and keeping slime and sludge deposits out of the flat spots in the lines.

PREAERATION INCREASES SEWAGE TREATABILITY*

By J. D. Walker

President, Walker Process Equipment, Inc.

In the early days of modern sewage treatment most sewer systems were constructed with open joints on the general belief that a little infiltration helped to move the sewage through the sewers faster and gave beneficial dilution that curbed objectionable odors. As more sewage treatment plants were built it was considered desirable to reduce the quantity of flow reaching the plant so that plant capacities, and thus construction costs, could be reduced. Accordingly, sewers were constructed with tighter joints which eliminated infiltration and reduced the volume of liquid flowing through the sewers.

The elimination of this more-or-less natural and continuous flushing of sewers lowered the flow velocity in many sewer systems to the extent that the flow became merely a displacement of sewage from pool to pool through the relatively flat sewers. Septic sewage was the result, but it did not cause much concern because the only treatment devices generally used were Imhoff tanks or settling tanks. Later, when secondary treatment oxidizing devices, such as contact beds, sand filters and trickling filters, came into vogue these were so over-designed as to be able to cope with the partially septic condition of many sewages.

Slowly but constantly increasing costs forced designing engineers to search for means of constructing complete treatment plants which would be less costly than their predecessors. Thus the era of reduced trickling filter size and activated sludge came into practice. Under present day conditions designers still find it necessary to reduce construction costs further and, accordingly, it will be necessary either to bring out new and more efficient secondary processes, or to increase the efficiency of primary processes.

On the whole, little has been done to increase the treatability of sewage taken into the modern secondary processes, the common practice being to receive the sewage "as is" in the plant and give it primary sedimentation. Then the operator is left to cope with stale sewage and operate the "reduced" trickling filter or activated sludge units as best he can.

After a break in a long protracted period of dry weather, during which time the sewage has become stale and less amenable to treatment, it is not uncommon for activated sludge plant operators to exclaim, "At last it has rained and the activated sludge has returned to normal." The rainfall, of course, would flush out the sewers and rid them of lurking pools of stale and septic sewage which caused all of the sewage reaching the plant to be stale and quite untreatable. In watching the operation of activated sludge plants, the marked difference in plant performance during and after a protracted dry spell has often been observed. Many plants stage very wonderful comebacks after a heavy rainfall has cleaned out the sewers and a more

* Presented at 20th Annual Meeting, Central States Sewage Works Association; Duluth, Minn.; June 22, 1947.

normal and treatable sewage reaches the plant for the next several weeks following such occasions.

A case in point is one of C. C. Larson's (Springfield, Illinois, Sanitary District) choice remarks, borrowed directly from "The Log of Important Events" in his Annual Operation Report, 1941:

"June 30. Activated sludge is bulking; sludge index 350.

"July 3. We had a very heavy rain yesterday and as usual the activated sludge 'got well' overnight. I wonder what there is in rain water that effects such a rapid recovery? I have a feeling that it is something more than just a freshening effect."

A Typical Example

A few years ago at Winfield, Kansas, the author had installed aeration equipment in a typically designed activated sludge plant and was engaged in the task of starting up the plant. The sewers at Winfield proved to be very flat and constituted a veritable series of septic tanks. The sewage received at the treatment plant was obstinately "untreatable."

Instead of the plant starting up in two to three weeks, after two months work it was still absolutely impossible to operate the plant with anything that even resembled an activated sludge. The sewage was stale and septic and was very resistant to being aerated into activated sludge. Consequently it was decided to change the flow pattern of the plant so that instead of using 12 hours for the activated sludge aeration period, 3 hours would be used for postaeration of the sewage, following primary sedimentation and ahead of the activated sludge return. This scheme worked no better than the first and then it was decided to alter the flow pattern completely so that 1½ hours would be used for preaeration ahead of primary settling, and the remainder would be used for activated sludge aeration. This worked like a miracle and the plant, overnight, turned into a normally operating activated sludge plant. The character of the sewage was changed in passing through the preaeration and primary settling tanks from a septic, untreatable mess to a sewage that lent itself well to activated sludge treatment.

Preaeration for Treatability

The word preaeration has been used to cover a multitude of sins and has included everything from a few seconds of intense aeration in a feed channel to an hour or two of adequate aeration preceding primary sedimentation. There is very little of the latter.

In the past, a limited amount of preaeration has been practiced by applying diffused air to head channels serving primary settling tanks. Ann Arbor, Michigan, is an example of this, where the sewage receives a scant few minutes of preaeration before entering the primary settling basin. Preaeration has also been practiced to a slight degree in so-called grease flotation tanks where the raw sewage was aerated for one to two minutes in a tiny basin before flowing into the primary settling tanks. A typical example of this is the unit as used at Springfield, Illinois, and later abandoned as being worthless, since the very short aeration period of one or two minutes accomplished nothing.

In this discussion, preaeration that does not "take" is not considered to be preaeration at all. Preaeration is practiced only when sufficient oxygen has been added to the sewage to permit a sample, properly taken, to show at least 0.2 p.p.m. D.O. upon standing in a D.O. bottle (submerged) for 60 minutes. This means that it may take 10 min. or 10 hours of aeration, depending upon how much oxy-

genation and agitation the waste requires, the intensity and efficiency of oxygenation, and other factors. Actually, if the preaeration is to be effective as such, it must be of such intensity and duration as to cause a definite beneficial end point.

Preaeration increases treatability by "killing" factors that oppose normal and efficient aerobic absorption and resynthesis in secondary processes. By reducing suspended particles that escape through the primary, and by eliminating "seed" that will cause the core of these particles to act anaerobically in desired aerobic surroundings, preaeration materially increases the ability of the secondary aerobic processes to take load.

Digester Supernatant

Another factor that destroys treatability of sewage is digester supernatant, when added to the primary settling tank. When separate sedimentation was first developed it was common practice to displace digester supernatant into the sedimentation tank where the entrained solids tended to settle. This caused no trouble when secondary treatment was not employed. This practice is still being carried on today. It has been found, however, that the supernatant acts as a seed to increase septicity in the protracted period of quiescence in the primary basin and results in a stale sewage more difficult to treat than it would be without contact with the supernatant liquor.

It is practical to preaerate digester overflow or supernatant to the point where that liquor will not cause or induce any putrefaction in a normal, fresh sewage and also to the point where supernatant will settle efficiently, dropping out the settleable solids and producing a clear, inoffensive overflow of low B.O.D.

Preaeration for B.O.D. and Solids Removal

One significant advantage of adequate preaeration ahead of primary sedimentation is that increased suspended solids and B.O.D. removal is accomplished in the primary settling device. This is particularly true with sewages that are stale or septic and is even true to a reasonable extent with sewages which by ordinary standards would be considered fresh.

Many factors enable preaeration to prepare sewage for gravimetric separation or clarification in settling tanks. One of the most important of these is the arresting of gas generation resulting from increasing putrescence during protracted off-hour retention periods in settling tanks. Another factor is the release of all previously entrained gases from the sewage particles. Gravimetric separation is a matter of specific gravity and if the flocculent particles in the sewage are buoyed up by gas bubbles they will not settle and, subsequently, will pass off with the primary effluent.

The writer has observed the operation of the Greenville S. C. sewage treatment plant with and without the use of preaeration. The visual difference in the primary settling tank was significant. Without preaeration the primary settling tank surface appeared turbid and carried a typical gray color. When preaeration was employed, the primary tank took on a remarkable and entirely different appearance. Objects could be observed 3 feet below the surface and the tank appeared surprisingly clear. This was also borne out by the difference in suspended solids and B.O.D. removal with and without preaeration.

A table of typical examples of the effect of preaeration on B.O.D. removal follows:

	Preaeration Period	Raw Sew. B.O.D.	Settled Sew. B.O.D.	Per Cent Reduction
Webster City, Iowa	30 min.	248	100	59.7
Rochelle, Illinois	20 min.	450	190	58
Rocky Mount, N. C.	30 min.			Reported over 65
Denver, Colorado	15 min. +15 min. floc.	240	113	52.7

It is considered that the data above are rather typical preaeration operating results and within the author's experience it is known that without preaeration, removal results are materially reduced. Unfortunately, in each of the above cases there is not enough long-time information to plot the results of operating without preaeration. In fact, many of the plants were incapable of by-passing the preaeration tank. It is time that considerable effort should be made to collect comprehensive data showing the effect of preaeration on primary settling and secondary treatment operation. There is little or none of this data available in the literature or in plant operation reports.

To the author's knowledge there are many other good unreported examples of the effect of preaeration, such as Winfield, Kansas, which gave a scant 25 per cent reduction without preaeration and well over 62 per cent reduction with 1½-hours preaeration. Two Navy plants in Florida (Yellow Water and Lake City), which provide one hour preaeration, effected well over 75 per cent B.O.D. removal through the primary settling tanks.

Floc Concentration

It is interesting and signficant to note that after a preliminary breaking-in period a rather stable colony of floc appears in preaeration tanks of adequate size. This floc may act as seed or a nucleus to effect increased particle growth and sedimentation. A raw sewage having a suspended solids content between 200 and 250 p.p.m. will build up a concentration of 300 to 350 p.p.m. in the preaeration tank. This concentration will be maintained more or less constant and will vary only slightly during the hours of the day. This is caused by floc which remains in the preaeration tank because of short circuiting. The best results from preaeration have been obtained concurrently with the presence of this floc build-up in the preaeration tanks. In fact, the author has made tests on preaeration tanks where the appearance and sedimentation characteristics of this floc build-up have been so noticeable as to raise the question whether chemical coagulant had been added to the raw sewage.

Odor Removal

At all plants where effective preaeration is practiced, it is noticeable that there is little or no offensive odor coming from either the aeration or the primary settling tanks. It has been proved that effective preaeration will oxidize all the hydrogen sulfide in the sewage. This fact was recently confirmed by tests conducted by Walter Sperry at the Lake Geneva, Wis. plant. Hydrogen sulfide in the raw sewage was effectively oxidized in the preaeration unit to the extent that when the preaeration unit was shut off, hydrogen sulfide became very noticeable.

Preaeration is being added to the plant at Aurora, Ill. to eliminate a corrosion and odor nuisance caused by hydrogen sulfide in the stale sewage

received at that plant. Mr. Sperry in the past has reduced hydrogen sulfide release by adding to the raw sewage river dilution water containing dissolved oxygen.

Need of Investigational Data

Related above are a few instances in which it was proved that preaeration was materially beneficial to plant operation. It is hoped that these instances may excite enough interest so that the many plants which are now capable of practicing preaeration will do so. In that way more will be learned about this extremely valuable aid to sewage treatment. To the author's knowledge, many plants are now equipped with tanks and so cross-connected that by the addition of simple aeration equipment preaeration could be practiced. In such plants it would be easily possible to compare long-time full-scale operation with and without preaeration and thus evaluate the importance of preaeration in future sewage treatment plant design.

As the expense of plant construction is not likely to decrease very much, it will be necessary to eliminate the large factors of safety that have been used in the past in designing secondary treatment devices. In doing so it immediately becomes necessary to pretreat ahead of these devices in order to eliminate as many operating variables and obstacles as possible.

Summary

Effective preaeration applied to domestic sewage of any degree of septicity will satisfy the chemical avidity of raw sewage for dissolved oxygen, will eliminate all hydrogen sulfide odors, and will cause the release of entrained gases of partial decomposition. Preaeration also will stop putrefaction in primary settling tanks thus eliminating further generation of gases which buoy up sewage particles and reduce primary sedimentation efficiencies. By increasing the "treatability" of the sewage, preaeration makes possible a reduction in secondary treatment capacity and in aeration and recirculation power requirements.

INTERESTING EXTRACTS FROM OPERATION REPORTS

The best place to find a helping hand is at the end of your arm.
—*The Clearing House*

Attention operators! **It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.**

Eighth Annual Report of the Racine, Wis. Sewage Disposal Plant and System for 1946

By Thomas T. Hay, *Superintendent*

Description of Sewage Treatment Plant and Sewer System

The treatment of sewage at Racine, Wis., is accomplished by primary treatment with chlorination and separate sludge digestion and sludge drying. Figure 1 shows the plant layout.

The plant treatment units are:

Prechlorination

Comminutors: 4 @ 12 m.g.d. cap. ea.

Mechanically cleaned grit chambers:

2—10 ft. by 40 ft.
1—20 ft. by 40 ft.
grit-washing equipment

Primary settling tanks: 1,500,000 gal. total cap.

Postchlorination

Digesters: 3—50 ft. by 50 ft. by 17 ft.

Sludge drying beds—glass covered

Submerged outfall to Lake Michigan.

The sewage is conveyed to the treatment plant by an intercepting sewer system consisting of 9.73 miles of sewers varying in size from 12 in. to 72 in. in diameter. In this system there are three pumping stations. Station No. 1 has a rated capacity of 20 m.g.d. This station has two pumps of 14 in. and 16 in. powered by synchronous motors of 125 and 175 hp., respectively. Station No. 2 has two sewage pumps with a total capacity of 0.6 m.g.d. Station No. 3 has a Flush-Kleen system of 0.5 m.g.d. capacity.

Administration

Operating Personnel

On January 7, 1946 the operating personnel was brought to its full strength for the first time since 1941. Present personnel consists of:

2 mechanics
1 mechanic's helper
4 operators
1 relief operator
5 utility men.

General Operational Notes

Visitors

Visitations are on the increase since war-time restrictions have been lifted. Although the number of visitors has not reached prewar levels, nevertheless there were fourteen states and six foreign countries represented among the visitors. The city government was represented among the visitors by five

alderman, three of whom were members of the Streets Committee, and seven city officials.

Several groups have used inspection trips through the plant for instructional purposes. Among these were student nurses from St. Luke's Hospital; Boy Scout groups; engineer students of Chain Belt Company; high school groups and students of the University of Wisconsin.

Salaries

Salaries have been established by the Finance Committee of the Common Council, as they have been for the past five years.

The operating personnel's salaries are augmented by a cost-of-living bonus which varied between $27.00 and $42.80 per month in 1946. The rates and earnings were as follows:

	Rate per Month	Total Earnings
Mechanic	$206.00 plus bonus	$2,856.90
Mechanic's helper	191.00 plus bonus	* 2,676.90
Operator	191.00 plus bonus	2,676.90
Utility man	186.00 plus bonus	2,616.90

Education

An in-training school was inaugurated on September 24, 1946. Attendance at this school is voluntary on the part of the employees who attend for one hour per week. Two-thirds of the employees have attended these classes. This has created improved interest in the plant operation and a better understanding of the plant problems.

Operation of the Plant

Flow

The plant treated 5,025 million gal. of sewage or an average of 13.8 m.g.d.

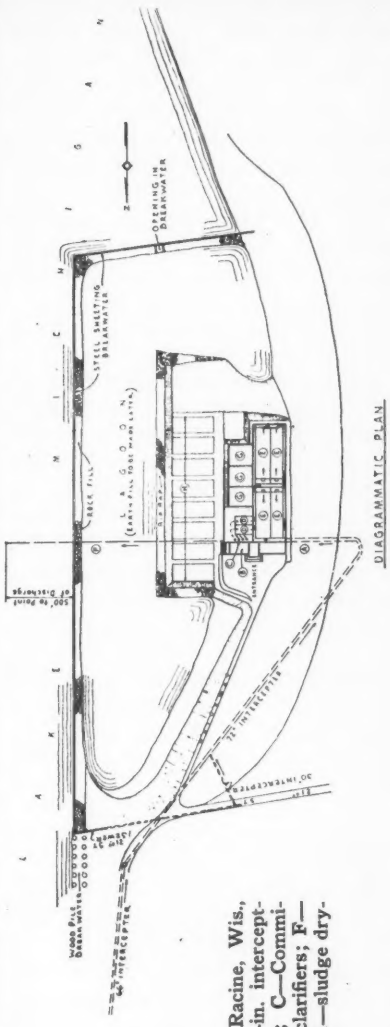


FIGURE 1.—Plant layout, Racine, Wis., sewage disposal plant. A—72-in. intercepting sewer; B—prechlorination; C—Comminutors; D—grit removers; E—clarifiers; F—effluent outfall; G—digesters; H—sludge drying beds.

This figure is 15 per cent over the designed capacity of the plant and has a very definite effect on nearly all of the results of treatment. The 1946 flow was 7 per cent greater than the 1945 flow and 51 per cent greater than the flow of 1939, the first full year of operation.

The flow per capita in 1946 was 73,903 gal., or 202 gal. per capita per day.

Operating Costs

There has been a large increase in the cost of operation in 1946 as there has been in the past five years. The increase has been almost entirely due to the increase in salaries. This is the first year that material costs have reached as high as in 1939, the first full year of operation, this in spite of the increased maintenance due to aging of plant and equipment. The total cost of operating the sewage treatment plant and intercepting system for 1946 was $60,018.31. This represents a per capita cost of $0.8826 or a cost per million gallons of sewage treated of $11.93.

Unusual Conditions in Operation

On April 20, 1946 the treatment plant was filled with hydrogen sulfide odor. The chlorine necessary to control odor jumped from 100 to 2,500 lb. per day. As the Fire Department received many calls on odor from the downtown area we worked with the Assistant Chief and the Plumbing Inspector and traced this to its source at the gas plant. It was found that they were dumping this waste in the sewer system. This waste was returned to the river and lake as previously done.

Table I is a summary of the 1946 operating data.

TABLE I.—Summary of 1946 Operation Data at the Racine, Wis. Sewage Treatment Plant

Item	Average
Total rainfall (in.)	24.28
Sewage flow (m.g.d.)	13.78
Per cap. sewage flow (gal.)	202
Settling tank retention (hr.)	2.6
Settleable solids:	
Influent (ml. per liter)	3.6
Effluent (ml. per liter)	0.2
Per cent reduction	94
pH:	
Influent	7.7
Effluent	7.8
Suspended solids:	
Influent (p.p.m.)	170
Effluent (p.p.m.)	80
Per cent reduction	53
B.O.D., 5-day:	
Influent (p.p.m.)	152
Effluent (p.p.m.)	95
Per cent reduction	38
Chlorine demand:	
Raw (p.p.m.)	8.1
Effluent (p.p.m.)	7.9
Raw sludge to digesters:	
Gal. per day	16,700
Per cent dry solids	7.17
Pounds dry solids	10,120
Per cent volatile solids	67
pH	6.6
Digested sludge:	
Pounds digested solids to drying beds	2,243
Per cent solids	8.73
Per cent volatile solids	48
pH	7.2
Per cent solids in supernatant	0.68
Analysis of dry sludge (%):	
NH_3	2.88
P_2O_5	2.25
K_2O	0.45
Grease	4.11
Humus	47.0
Moisture	43.0
Gas, cu. ft. per capita per day	0.7
Gas analysis:	
B.t.u.	655
Oxygen (per cent)	1.3
Nitrogen (per cent)	1.2
Hydrogen (per cent)	1.2
CO_2 (per cent)	31.4
CH_4 (per cent)	65.7
Operating costs ($):	
Per capita	0.88
Per m.g.	11.93

Annual Report on the San Diego Sewage Treatment Plant for the Fiscal Year Ending June 30, 1947 *

By Eric V. Quartly, *Superintendent*

Sewage Flow

The total quantity of sewage treated during the year amounted to 7,587 m.g. as compared with a total of 8,238 m.g. the previous year.

Cost of Operation

General salary increases plus higher material and supply costs resulted in a 10 per cent increase in the gross operating cost of the plant. This increased operating cost together with a 15 per cent decrease in the amount of sewage entering the plant has resulted in a net operating cost of treatment for the fiscal year of $12.58 per m.g. as compared with a cost of $10.72 for the previous year.

Fertilizer

During the year, 1,249 tons of fertilizer have been produced and with the exception of sales to other city departments all fertilizer has been sold by contract. The former contract which expired on June 30, 1946, was renegotiated on the basis of $20.00 per ton F.O.B. plant storeroom, with sacks being furnished by the contractor.

Safety

Personnel training in safety and sanitary measures has been carried on throughout the year with regular monthly safety meetings being held at the plant. Many excellent suggestions made by the operating and maintenance staff at these meetings have been put into effect. To date the employees have worked a total of 709 calendar days without a disability accident which represents approximately 168,000 man-hours. The plant personnel was awarded the city manager's Safety Award for 1946 at a banquet attended by 28 of the 31 employees.

Laboratory

Full laboratory control has been maintained throughout the year on all treatment processes with a total of approximately 2,700 analyses having been made from samples taken.

Considerable laboratory work has been accomplished in determining sulfide concentrations in the Point Loma and Mission Beach sewer systems preliminary to establishment of chemical pretreatment stations in these areas to reduce corrosion and odor problems cause by hydrogen sulfide.

Contaminated Garbage

During the last two months of the year the plant has been receiving small quantities of contaminated garbage collected by the Refuse Department from tuna fishing boats in compliance with the regulations of the California Department of Agriculture which requires that all such garbage be ground or incinerated. This garbage is ground in the screenings grinder and mixed with the incoming raw sewage for treatment.

Grit Removal

Although the Detritor has been in operation continually during the year the quantity of grit removed has been far below normal due to the continuance of the overloaded condition and the high flow velocities through the Detritor basin. Grit has been broadcast on the plant grounds and treated with DDT spray for fly control. Total quantity removed for the year amounted to 140 cubic yards.

* For last previous extract see This Journal, 19, 3, 503 (May, 1947).

Vacuators

Last September it was decided to bypass all sewage past the two Vacuators and place them on standby status in order to reduce the quantity of liquid being pumped to the digesters. Due to the peculiar flow conditions existing at the Vacuators, variations in flow resulting from pump action caused a considerable fluctuation of the water level in the Vacuators with the result that a considerable volume of sewage was swept over the scum trays with the skimmings. This condition was aggravated by the overloaded condition of the Vacuators.

Digestion System

Heating of the primary digesters has been accomplished by preheating raw sludge with steam only. The steam boiler has given good service and has been in continuous service except for a few days shut down to permit cleaning of tubes and removal of scale deposits by use of hydrochloric acid.

Elutriation

Both elutriators have been overhauled during the year and all structural steel below and above water repainted. Considerable trouble has been experienced with the three horizontal Scru-Peller pumps used for pumping digested and elutriated sludge. The wear on the pump impeller shafts and cutter bars has necessitated replacements on all these pumps in addition to a replacement with a new pump in the early part of the year. (Editor's Note: This is undoubtedly the result of the inefficient grit removal obtained in the overloaded Detritor.)

Sludge Dewatering and Drying

Both vacuum filters have been in service the entire year except for a two week overhaul period. It has been necessary to remove and recondition the filter valves, renew the cedar backing strips and to replace the monel screens due to buildup of ferric chloride deposits.

Due to increasing the space between the cedar backing strips, it has been possible to greatly increase the life of the wool blankets. The average blanket life this year has been 1,000 hours, as compared to 750 hours last year.

The quantity of ferric chloride required for conditioning sludge has shown an increase over last year's rate of 6.02 per cent to an average of 6.31 per cent. This abnormal dosing rate is due to our inability to adequately wash sludge in the overloaded elutriators and to the lack of digester capacity.

The operation of the heat drying system has been satisfactory during the year but wear due to excessive quantities of sand has necessitated numerous repairs and replacements. Major items accomplished this year are as follows:

Installation of larger belt sheaves, new shafts and bearings on both vapor and draft fans to reduce vibration and increase operating safety.

Replacement of original vapor fan wheel with new fan. Old fan blades had worn completely through in some places.

All cage mill bars in the flash dryer have been renewed, as have the worn paddles in the sludge mixer.

The dust explosions that have occurred from time to time during the last three years have caused considerable concern and, in line with the manufacturer's recommendations, steam facilities have been installed to permit flooding the system with steam during the shut-down procedure or at times of power failure. The installation of steam lines was completed early in January and it is significant to note that to date no dust explosions have occurred and the shut-down procedure

has been simplified. Steam injection is made at the entrance to the dryer cyclone and flash dryer.

Chlorination and Odor Control

The new 1,000 lb. per day chlorinator and the chlorine evaporator were placed in operation in August, 1946. The additional chlorinator has provided ample capacity for high chlorine demands and for standby service and the chlorine evaporator has completely eliminated the previous trouble of "freezing" of chlorine piping and equipment.

Since September last, all chlorine consumed for sewage treatment has been purchased in 16-ton capacity railroad tank cars. In order to accommodate these tank cars it was necessary to extend the city owned railroad spur, install chlorine supply piping, and erect safety handrails and service platform. The results from this installation have been very satisfactory. In addition there has been a reduction of approximately 27 per cent in the cost of chlorine. A material saving of time has been experienced due to the elimination of handling the one-ton cylinders.

The manufacture of ferrous chloride for odor control has been continued during the year as required. The application of both ferrous chloride and chlorine have been controlled by sulfide determinations both in the incoming raw sewage and in the sedimentation tanks. Table II is a summary of the 1946–47 operating data.

TABLE II.—Summary of Operation Data for 1946–47 at San Diego, Calif.

Item	Average
Total rainfall (in.)	6.33
Sewage flow (m.g.d.)	20.8
pH raw sewage	7.7
Suspended solids:	
Raw (p.p.m.)	326
Effluent (p.p.m.)	110
Removal (%)	66.5
Raw sludge:	
pH	6.4
Dry solids (%)	5.6
Volatile solids (%)	79.2
Digested sludge:	
pH	7.3
Dry solids (%)	4.0
Volatile solids (%)	60.0
Alkalinity (p.p.m.)	4,350
Sludge dewatering and drying:	
Wet cake produced (tons per mo.)	439
Dry solids in cake (%)	25.2
Cake yield (lb. per sq. ft. per hr.)	1.37
Ferric chloride (% on dry solids)	6.31
Moisture content fertilizer (%)	11.57
Elutriation:	
Dry solids (%)	4.2
Volatile solids (%)	59.7
Alkalinity elutriated sludge (p.p.m.)	1,227
Alkalinity wash water (p.p.m.)	339
Chlorination and Scott-Darcey process:	
Cl_2 used (lb. per mon.)	22,400
$FeCl_3$ (Scott-Darcey) used (lb. per mo.)	2,520
Metal used (lb. per mo.)	2,005
Total operating cost ($)	121,463.85
Revenue from sale of fertilizer ($)	24,787.00
Net operating cost ($)	96,676.85
Total operating cost per m.g. ($)	
Labor	7.93
Materials and supplies	4.39
Power	2.05
Overhead	1.48
Total	15.48
Net operating cost per m.g. ($)	12.58

Annual Report of the Operation of the Detroit, Mich. Sewage Treatment and Disposal System for the Fiscal Year Ending June 30, 1946

By Fred H. Burley, *Engineer of Sewage Treatment*

Pumping Station Operation

All six main pumps were used as required, with only individual ones being out of service for routine repairs or for the overhauling of the attached screening and grit collecting equipment. During the period of ferric chloride shortage routine pump-downs

of the interceptors were discontinued and the water level kept high to limit the quantity of solids brought into the plant.

The total sewage pumped for the year amounted to 120,119 million gal., or 4.6 per cent more than the previous fiscal year. The average daily pumpage increased to 329 m.g.

Higher interceptor levels during the year resulted in reducing the pumping costs from 115 to 113 kw. per m.g.

Rack and Grit Building

A year's trial of grinding the rakings and returning them to the sewage flow has indicated that this method is satisfactory enough to warrant further use and improvement. The rapid dulling of the hammers is being solved by adding a hard alloy tip to the wearing edges. Eighty tons of rakings were sent directly to the incinerators during several experimental periods.

Grit removed amounted to 21,293 wet tons, which is an increase of 46.3 per cent over the previous year. This increase can be traced to a number of causes, such as the greater use of the "cold patch" for street repairs, increased vehicular traffic, accelerated construction activity with its new sewer connections and building materials stored along the curbs.

Sedimentation Tanks

All eight sedimentation tanks have been in use during the year except for periods of repair or observation. Both east and west pressure tunnels were drained and the grit deposits in them observed and plotted. The grit was left in place as it had formed its own natural channel.

The frequent plugging of the grease pumps is still a major problem, due to the large amount of wood sticks (some as large as 2 in. by 4 in.) which are picked up.

Screens in the collecting hoppers have been tried with openings of 1½ in., 2 in., and 3 in., but they quickly sealed over and failed to let the grease pass through. Further study is underway to provide a means of grinding up sticks prior to their entry into the pump impeller.

During the summer months the foamy condition of the grease and scum caused numerous pump stoppages due to gas binding. This sometimes cleared itself, but more often required stopping and restarting of the pumps.

Digester

The digester was out of service during July and August for cleaning and observation. It had been drained of all liquid in June, and the remainder of the matted material pumped out with much difficulty during July.

All of the metal framework was found to be in good condition, having accumulated a protective lime-like coating during its five-year use. The under side of the floating cover was likewise well protected by the oil which had risen to the top of the sludge.

Filter Building

Continual experimentation with the filtering equipment is producing greater production with less chemical dosages. The lime percentage has dropped for the third consecutive year, this time from 7.0 to 6.7 per cent. Filter cake yield has increased from 6.8 to 7.0 lb. per sq. ft. per hour. The ferric chloride dosage increased from 2.08 to 2.31 per cent, due in some measure to filtering difficulties encountered during the shortage of ferric chloride.

Equipment is now being installed to dilute the ferric chloride with water just prior to its use. This will permit more accurate dosing and a wider dispersion of the material in the sludge.

Several important piping changes have been made, all with the idea of protecting the vacuum pumps from

TABLE III.—Detroit Water and Sewage Disposal Rates

Rate Steps	Water Rate per M. Cu. Ft. $	Sewage Disposal Rate per M. Cu. Ft. $	Total Rate per M. Cu. Ft. $
Consumption Charge:			
First 10,000 cu. ft. per month	0.78	0.11	0.89
Next 90,000 cu. ft. per month	0.60	0.11	0.71
All over 100,000 cu. ft. per month	0.48	0.11	0.59
Monthly Service Charge:			
Meter Size			
⅝ inch	0.24	—	0.24
¾ inch	0.36	—	0.36
1 inch	0.72	—	0.72
1½ inch	1.44	—	1.44
2 inch	2.40	—	2.40
4 inch	4.32	—	4.32
8 inch	11.04	—	11.04
12 inch	18.72	—	18.72
24 inch	53.28	—	53.28

Service charge is added to consumption charge and shown on the bill as one item.
Minimum bill..... $1.50 per quarter

TABLE IV.—Suburban Water and Sewage Disposal Rates Charged by the Detroit Department of Water Supply *

Rate Steps	Water Rate per M. Cu. Ft. $	Sewage Disposal Rate per M. Cu. Ft. $	Total Rate per M. Cu. Ft. $
Consumption Charge:			
First 10,000 cu. ft. per month	0.82	0.25	1.07
Next 90,000 cu. ft. per month	0.63	0.25	0.88
All over 100,000 cu. ft. per month	0.50	0.25	0.75
Monthly Service Charge:			
Meter Size			
⅝ inch	0.50	—	0.50
¾ inch	0.62	—	0.62
1 inch	0.98	—	0.98
1½ inch	1.70	—	1.70
2 inch	2.66	—	2.66
4 inch	4.58	—	4.58
8 inch	11.60	—	11.60

Service charge is added to consumption charge and shown on the bill as one item.
Minimum bill..... $2.32 per quarter

* Rates not applicable to suburban municipalities covered by master meters.

getting water in their cylinders and avoiding interruptions in filter production. These changes are: (1) large drains on the moisture traps; (2) one instead of two drum traps for the moisture trap drains; (3) the splitting of the vacuum system to permit work on one-half at a time; (4) the connecting of the filter-pan drains directly to the yard sewers.

Experiments have been made with small areas of filter cloth woven of

TABLE V.—Summary of 1946 Operating Data at Detroit, Mich.

Item	Average
Rainfall, total (in.)	30.47
Sewage temperature, ave. (°F.)	62
Connected population	2,300,000
Sewage pumped (m.g.d.)	329
Solids removed:	
Rakings (tons):	
Wet	80
Dry	16
Volatile	13
Grit (tons):	
Wet	21,293
Dry	10,554
Volatile	5,190
Sluiced wet	4,300
Tank scum (tons):	
Wet	1,474
Dry	956
Volatile	859
Suspended solids (tons):	
Dry	63,001 [1]
Volatile	42,211
Total solids (tons):	
Dry	74,527
Volatile	48,273
Analytical data:	
Suspended solids:	
Influent (p.p.m.)	255 [2]
Effluent (p.p.m.)	116
Per cent reduction	54.5
B.O.D.:	
Influent	132
Effluent	80
Per cent reduction	39.3
Grit, per cent solids	47.4
Grit, per cent volatile	37.8
Raw sludge to digester:	
Per cent solids	9.1
Per cent volatile	65.0
Sludge digestion:	
Gal. added (1,000)	22,700
Dry solids added (tons)	9,016
Loading rate, lb. per cu. ft. per month	5.5
Gal. withdrawn (1,000)	21,879
Dry solids withdrawn (tons)	5,550
Gas produced:	
1,000 cu. ft.	109,118
Cu. ft. per lb. vol. sol. added	9.25
Supernatant:	
Per cent solids	6.1
Per cent volatile	53.8
Sludge filtered:	
Mixed sludge to filters:	
Per cent solids	9.1
Per cent volatile	65.0
Thousand gal. filtered	104,147
Dry solids (tons)	39,416
CaO used (tons)	2,650
CaO used (per cent)	6.7
$FeCl_3$ used (tons)	910
$FeCl_3$ used (per cent)	2.3
Yield (lb. per sq. ft. per hour)	7.0
Sludge cake:	
Per cent solids	30.7
Per cent volatile	58.4
Incineration:	
Wet (tons)	160,339
Dry (tons)	53,089
Volatile (tons)	29,077
Wet feed per incinerator (tons per hour)	8.0
Fuel oil per wet ton burned (gal.)	0.08
Electric power (100 kw.-hr.):	
Purchased	170,180
Generated	6,337
Total used	176,517
Main pumps	135,735
Auxiliary power	40,782
Kw. per m.g. (pumping only)	113
Chlorination:	
Chlorine demand (p.p.m.)	7.77
Chlorine applied:	
Tons	2,636
p.p.m.	5.29
Per cent demand satisfied	68.1
Coliform indices:	
Influent × 1,000	5,717
Effluent × 1,000	708.9
Per cent removed	87.61
Accident frequency rate (disabling injuries per million man-hours)	17.57
Accident severity rate (days lost per thousand man-hours)	0.343

[1] Suspended solids corrected for included grit.
[2] Includes grit during 11 months.

plastic threads. The results from the first trials were not very encouraging, due to the rapid filling of the mesh with the lime deposit. Further experiments are being made.

Incineration

Continued efforts are being made to increase, economically, incinerator capacity. Accordingly, storage bins and screw feeders have been installed on two of the four units. A variable deflector plate has been added on the top hearth of incinerator No. 5 to spread the cake more evenly. This plate along with a larger bypass drop hole permits additional feed and fire control and has resulted in more uniform temperatures.

The preheater units of No. 2 and No. 3 incinerators have been dismantled and are now up for sale. These units were used only for short periods of experimentation.

Linear travel speeds were reduced approximately 28 per cent on certain rubber conveyor belts, to reduce the wear caused by the scraper and thus prolong their life. Side-skirt plates were removed where possible and spread where additional capacity was required.

Fuel oil consumption has decreased from 0.14 to 0.08 gal. per wet ton incinerated, a drop of 42.8 per cent. Fuel oil used dropped from 26,292 to 13,120 gal., a decrease of over 50 per cent.

Boilerhouse

The boilers continue to operate almost exclusively on digester gas. Fuel oil was required only during repairs to the gas blower or gas line. Fuel oil consumption dropped from 3,517 to 2,814 gal., a decrease of almost 20 per cent.

Chlorination

The average chlorine demand of the sewage dropped from 8.24 to 7.77 p.p.m., and the total amount used decreased 11.8 per cent. This reduction is largely due to curtailed applications during the winter months.

Laboratory

Control of chlorine applications has continued on a 24-hour, 7-day per week activity.

Miscellaneous

Flies, mosquitoes and other insects have been successfully combated in certain areas of the plant by the spraying of DDT on walls and ceilings.

A metalizing spray-gun was purchased during the year. Its use has simplified several maintenance jobs and reduced the costs on others.

Rates

Tables III and IV show the water and sewage disposal rates charged for Detroit and suburban services.

Operation Data

Table V is a summary of the operating data for the year ending June 30, 1946.

BARK FROM THE DAILY LOG

By Walter A. Sperry

Superintendent, Aurora (Illinois) Sanitary District

September 10—We are proud of the latest addition to our group of public exhibits. Others may like the idea and are welcome to copy it. The exhibit consists of an 8-ft. by 5-ft. panel. At the top is the heading: "Rivers Are an Asset of the Whole State—to be Enjoyed by All Its People." Beneath, are four frames labeled, respectively, Boating, Fishing, Picnicing, and Beautiful Scenery. Each frame contains five 5-in. by 7-in. enlargements of Fox River scenes appropriate to the title. There are two favorite shots, one showing a swimming hole with about 40 children swimming. The other was taken just across the river from the Aurora plant. Four women, sitting on camp stools along the river bank, are busily "klacking," with their families round-a-bout, enjoying a beautiful Sunday morning. Some day we shall display this exhibit in a downtown store window to encourage the work of the local Park District recently organized for the purpose of acquiring, preserving, and developing park areas along the river in the vicinity of our plant.

September 25—September 19th and 20th our Sanitary District was host to the annual meeting of the Illinois Association of Sanitary Districts. Over one hundred members and guests enjoyed the two days together. The many nice things that were said at the conclusion of the meeting were ample pay for the weeks of preparation and the two or three weeks of aftermath. When one's own District president is president of the Association, one is really on the "hot seat."

The details of preparing an adequate program, arranging a banquet with entertainment, providing hotel and parking accommodations, organizing registrations, planning a visit to the plant, preparing news items, etc. *ad infinitum,* seem to multiply into a million items. This does not include the side issue of having a spotless plant ready for the inspection of the visitors. It is all well enough to have people think that one's plant is always ready for inspection. The real truth is that plenty of fresh paint, window washing, and redding up inside and out were what really saved any embarrassment.

Then too, one can't think of everything. While listening to a lovely concert the night before the meeting, your Logger suddenly remembered (why we do not know) that he had forgotten to display a fine example of English pottery, shaped like a bed room vessel, which was to be filled to overflowing with flowers as a humorous reminder of an older day in sewage treatment.

The last Sanitary District meeting at Aurora had been in 1930. When it was over we did not care if the next time was not until 1964. Yet this was not so, for the over-all experience is delightful and well worth repeating as often as the group desires to come.

October 2—There is no accounting for accidents. A potential accident spot may exist for years and escape detection until some day it becomes painfully obvious. Last night, the night operator narrowly missed a sprained ankle, or worse. One of the gratings over the channels feeding the secondary settling basin had an open gap of about four inches at a stop plank slot. The opening was out of the usual line of travel but the night operator's foot found it. All that was required to eliminate this hazard was to shove the

grating over the slot and apply a 2-in. by 4-in. inch dutchman at the other end to take up the gap. At the same time another grating which had been pulled back to expose a 6-in. gap for sampling purposes was shoved back into place and a protected 6-in. by 6-in. opening cut in the grating in place of the gap. A no-accident record is obtained only at the price of eternal vigilance on the part of all—including the boss!

October 10—The latch string is always out on the front door of the Aurora plant, especially to visitors who "want to look at the engines," or who enjoy reading this Log. It is not always easy to discipline one's self into the frame of mind necessary to start a new Log and an occasional visit by someone who enjoys the Log is always an inspiration. Mr. A. Preston Collins, sewer design engineer of the Los Angles County Engineer's office, stopped for a visit today. Apparently a visit with your Logger was one of the "musts" of his trip East. We spent a pleasant half-hour looking over the plant and Mr. Collins' comments on western experiences with waste disposal problems were extremely interesting.

Another visitor this afternoon was Ross J. Buck, an engineer from Edinburgh, Indiana. It was six o'clock before we stopped discussing the operation of the gas engines. Monday morning a long distance call found him in Chicago, sitting at the desk of our engine's Sales Manager in Chicago. Evidently Mr. Buck liked what he saw of our engines.

October 15—In a day when lumber is as expensive as beef steak, these notes on the efficient use of nails seem worth sharing. Thomas H. McKaig, consulting architectural engineer of Buffalo, New York, writing in a recent issue of the *Engineering News-Record* has this to say: Nails driven in holes 1/32 to 1/16 inch smaller than the diameter of the nail will have greater resistance to shear and pull than nails driven without holes. The length of nails should be a little more than twice the thickness of the member holding the heads. Cement-coated nails hold more securely than uncoated nails.. Slender nails resist repeated shock and weaving action better than thick nails. They bend without losing their grip at the point. Short pyramidal points hold best; nails with blunt or sharp points do not hold as well. Cut nails driven with the taper sides parallel to the fiber of the wood resist withdrawal better, but are more liable to cause splitting.

October 21—More trouble in the offing. We received word today that Armour and Company is planning a $3,000,000 animal pharmaceutical products plant in Aurora. They plan to pump 3,500 gal. per min., from the Fox River, returning 2,800 gal. to the river and sending a million gallons per day to us, with their compliments!

November 2—Speaking of safety always connotes fire prevention and protection. Several years ago we made a considerable expenditure for an assortment of fire protection apparatus that consisted of Pyrene guns, soda-acid tanks, a 40-gal. Foamite wagon, and two reels of hose which were placed in the Clarifier house. This purchase was made just prior to the advent of CO_2 apparatus. None of it was ever used. The Foamite wagon was a continual nuisance for want of a place to put it. Not too much care was taken to recharge annually the apparatus and recently we junked the whole outfit, because of deterioration. After discussing the matter with the engineer-inspector of our insurance company, we plan to replace what now seem, to us, to have been misfits with a selection of CO_2 extinguishers and Pyrene guns. A careful study of our likely fire hazards indicates our danger is confined to Class B and C

fires, which are best fought with CO_2 and/or Pyrene (carbon tetrachloride) extinguishers.

The following tabulation will prove helpful in selecting the proper type of fire extinguisher equipment:

Class of Fire	Type of Extinguisher				
	Foamite[1]	Acid-Soda[1]	Anti-Freeze[2]	Pyrene[3]	Carbon Dioxide[3] (CO_2)
A (wood, textiles, rubbish, etc.)	Yes	Yes	Yes	No	No
B (oils, greases, etc.)	Yes	No	No	Yes	Yes
C (electrical machinery)	No	No	No	Yes	Yes
D (pleasure automobiles, commercial trucks, etc.)	No	No	No	Yes	Yes

[1] Foamite and acid-soda types are affected by low temperature.
[2] Anti-freeze is an acid-soda type adjusted to 40° below zero (F).
[3] CO_2 and Pyrene are not affected by temperature.

November 15—As luck would have it, last summer, just a week before our Illinois Sanitary District Association visitors were scheduled to arrive, we found a big hole in the 4-in. gas line that supplies the incinerator in the Screen House. The leak was located at the drip manhole on the line. This meant digging up about 20 ft. of lawn to make repairs. That portion of the pipe buried in the ground was as sound as a nut and we cut it off and saved it. The part exposed in the manhole was badly corroded. Neither of our supply houses had any 4-in. pipe, either in Aurora or in Chicago. A good plumber friend recognizing our dilemma, "lifted" a length (at $23.50) from a next door factory job. We made repairs in time to restore service and took care that "this can't happen again." We dug the dirt from around the pipe for a foot or more back from the face of the manhole wall and encased all the exposed portion of the pipe in a fairly thick jacket of coarse sand and cement.

November 20—The shear pins have been breaking on the drive mechanism of our secondary settling tank. On pumping the tank down, it was discovered that the barrel end of the links in the cross-flight chains had worn clear through, and even a little into the chain bolts. This was a surprise! Some gravel and a very considerable amount of small snail shells were cleared out of the sludge channel, but this did not account for the shear pin trouble. The long flight chains were in good order probably due to their less amount of travel.

A call for help brought a friendly, traveling trouble-shooter. He decided that we had not taken enough slack out of the long flight chains. Then we found some eight flights had loosened and were cramping along the bottom, and, finally, that the shoes on the ends of the flights which rubbed along the return rails had become grooved enough so that occasionally they caught on the gusset plate supporting the return rails. As shown in Figure 1, a welder cut the gusset plates down about ¾ inches to clear the shoes. The shoes that rode the rails on the floor of the tank were not nearly so worn, due to the lubricating effects of the sludge. Because the tank dried out while it was empty the assistance of a good chainfall pull was required to help the sludge collector motor pick up the load.

As the tank filled with water we were able to gradually reduce the

FIGURE 1.—Welder cutting down gusset plates supporting return rail of sludge collector.

size of the shear pins until normal operation could be resumed. It was decided that the cross-flight chains would run safely enough until early summer when the weather would be better for rechaining. Chain could not possibly be obtained before mid-winter. In the meantime, orders were immediately placed for chain. The surprise was that whereas the sprocket wheels seemed in perfect condition we were strongly urged to order new sprockets as well as the chain. We confirmed this elsewhere. It seems to be a rule never to put new chains on old sprockets, or vice versa.

The second day after the tank was returned to service the sludge line from this tank plugged. After exhausting all other methods, we finally pumped the tank down again expecting to find another worm can. But the trouble proved to be another slug of snail shells that had been swept into the tank from the connecting channels. Now we are trying an intercepting dam between the filter channel and the tank.

December 1—We argued for ten minutes over the telephone today with a woman who called to insist that there was a federal law that forbade the building of sewage treatment plants within a city limits, and especially near a residence district. "Why," she said, "what about the children playing about?" We do not know yet what started that argument. She hung up a little peeved not to be confirmed in her ideas.

EXTERIOR CORROSION OF CAST IRON PIPE*

By Kirk H. Logan

Special Representative, The Cast Iron Pipe Research Association, Washington, D. C.

Under most soil conditions properly made cast iron pipe does not corrode easily. There are many cities in which cast iron water, gas, and sewage force mains have served for over a century and are still in use. In some European cities cast iron pipe has served

* Presented at the 12th Annual South Dakota Water and Sewage Works Conference; Deadwood, S. D.; September 20, 1946.

for even longer. This freedom from corrosion is so general that there are few articles dealing with exterior corrosion of cast iron pipe to be found in the publications of the sewage works field.

There are, however, a few conditions under which all ferrous materials corrode rapidly. Those engaged in the maintenance of sewage force mains and sewage treatment works should be acquainted with the causes of such rapid corrosion, be able to recognize corrosive conditions and be familiar with the methods commonly used in preventing corrosion under each condition. There are several different circumstances under which iron corrodes and each such circumstance requires a different remedy.

Causes of Corrosion

Although there is but one fundamental cause of underground corrosion, a difference of electrical potential between the metal and the adjacent soil, several secondary causes may be recognized. Among the more important of these are: (1) stray currents from electric railways; (2) differential aeration; (3) soil alkali; and (4) bacteria.

Stray Current Corrosion

Stray electric currents, the corrosive effect of which is commonly known as "electrolysis," usually originate in the operation of street railways, although currents also sometimes come from mines. Alternating current such as is carried by power lines does not cause corrosion under ordinary conditions and the grounding of telephones, lighting circuits and radios seldom causes corrosion.

Stray current electrolysis is becoming less important as street railways are replaced by buses, but in small cities there are frequently periods in which street railway tracks are poorly maintained and current leaking from the rails may cause damage to sewage force mains located in the neighborhood of generating stations, and occasionally in other locations.

Differential Aeration Corrosion

A more frequent cause of corrosion is differential aeration. If part of a pipe line or network lies in a soil from which the air is excluded while another part lies in a soil which the air can penetrate freely, the difference in the oxygen concentration in the soils results in an electric cell which furnishes a corrosion current. The metal corrodes in the soil from which the air is excluded. Such a condition may be set up when a pipe traverses a heavy clay soil and an adjacent sandy soil, or when a large pipe lies in a trench partly filled with water. Differential aeration may also occur if the pipe lies on the uneven bottom of an improperly backfilled trench or in a heavy soil which cracks badly in drying out.

It is almost impossible to maintain absolutely uniform aeration along a pipe line. The corrosion resulting from this lack of uniformity may be negligible or serious, depending on the character of the soil and of the corrosion products that are formed. Fortunately most corrosion products of cast iron tend to retard corrosion.

Alkali Corrosion

In certain parts of the country where the rainfall is low, salts usually known as alkali, collect. These salts may be alkaline or neutral in chemical reaction. Salt-bearing soils are usually corrosive because they lower the electrical resistivity of the soil and so aid the flow of current which always accompanies corrosion, or because they break down and form corrosive chemicals such as sulfuric acid or sulfides. Alkali soils, especially when irrigated, are a common cause of corrosion west of the Mississippi.

Corrosion may also be severe in wet soils which contain little alkali. There are several ways in which this may occur. When adjacent to drier sandy soils they form the corroding element in a differential aeration circuit as explained above. Wet soils are favorable to plant growth, and swamps and peat bogs may be corrosive because of decaying vegetation.

Bacterial Corrosion

Wet soils are usually poorly aerated because the water retards circulation of air and because the decaying vegetation takes the oxygen from the water. Wet soils are, therefore, favorable for the growth of anaerobic bacteria which indirectly cause corrosion.

The relation of some of these bacteria to corrosion has become generally known only within the last decade and there is still some doubt as to their importance as corrosive agents. Briefly, it is believed that a strain of anaerobic sulfate-reducing bacteria known as *Sporovibrio desulfuricans* causes corrosion either by (1) removing the hydrogen film which usually forms on a corroding surface and polarizes it, thus retarding further corrosion, or (2) forming a sulfide which attacks the metal. For actual growth these bacteria require a nearly neutral, oxygen-free soil which contains organic matter and a sulfate. It has been found possible to correlate their activity with rapid corrosion of iron.

Identification of Corrosive Conditions

Having the causes of corrosion in mind, the sewage works superintendent has a basis for the recognition and possible avoidance or elimination of corrosive conditions.

If the soil is light in texture and well drained, it is unlikely that the soil is corrosive to cast iron. A good agricultural soil is usually noncorrosive if free from stray currents.

Heavy clay soils, especially if subject to shrinkage and cracking in dry weather, may be corrosive because of the differential aeration circuits which they create. Heavy, wet soils and organic soils such as muck and peat may be corrosive for several reasons. Dry alkali soils may sometimes be recognized by the salt incrustations on the surface, or the salt crystals in the soil. Most alkali soils have low electrical resistivities because of the conductivity of the salts in solution. There are several kinds of inexpensive, easily operated apparatus for determining the resistivity of soils in the field or in the laboratory. Usually a soil with a resistivity less than 500 ohm-centimeters is corrosive, but there is no close relation between soil resistivity and corrosion because other things also affect the rate of corrosion. Nevertheless, an apparatus for determining soil resistivity more than pays for itself if used frequently in country containing alkali soils.

It is difficult to directly determine the presence of sulfate-reducing bacteria in soils. They are found to some extent in most poorly aerated soils. Their activity is greatest in unaerated soils containing organic matter and sulfates and where such conditions are found it is safe to assume that bacteria are active. If an iron pipe has been buried for a long time where the bacteria are active, there will be an accumulation of iron sulfide in the soil adjacent to the pipe. If a little of this sulfide-containing soil is placed in a test tube and dilute hydrochloric acid added, hydrogen sulfide, recognizable by its odor, will be evolved. Do not put hydrochloric acid on so-called graphitic corrosion products. They usually contain enough sulfur compounds to produce some hydrogen sulfide even in the absence of the bacteria.

An instrument for determining the aeration of wet soils has been patented. It is helpful in locating soils favorable

to anaerobic bacteria, but does not locate bacteria directly.

Prevention of Corrosion Losses

There are several ways of avoiding the effects of corrosive soils, each of which is very satisfactory under some conditions and less so under others.

The prevention of stray current electrolysis is an electrical engineering problem which generally should be undertaken only by someone specializing in this line of work. Amateur work frequently causes as much trouble as it cures.

In principle, the objective is to prevent stray current from flowing from the pipe to the earth and at the same time to avoid damage to other structures. Electrolysis and measures used to prevent it usually affect all structures in the same territory including water, gas, and oil pipes; telephone and power cables; metal conduits; and any other buried conductors. For this reason, electrolysis problems should be solved jointly by all parties affected. A number of cities have electrolysis or corrosion committees for this purpose. The application of cathodic protection should be similarly handled.

Special corrosion resistant alloys have been developed for resisting atmospheric corrosion and for handling various corrosives in chemical industries. Many of these alloys have also been offered for underground service to resist soil corrosion. It is true that alloying iron with high percentages of chromium and nickel produces very corrosion-resistant material. This, however, is too expensive for general use. Extended tests and experience have so far indicated that none of the low-alloy steel or iron has any significant advantage in corrosive soils over ordinary unalloyed cast iron.

In most soils much of the corrosion product is deposited on the pipe or in the soil close to it and this deposit tends to reduce the rate of corrosion as the thickness of the deposit increases. For this reason the pipe with a wall thickness sufficient to maintain service until the layer of protective corrosion products becomes effective, lasts much longer than a thin-walled pipe.

Usually the corrosion of cast iron is of the so-called "graphite" type which tends to plug any pits that are formed. This so-called "graphite" usually contains less than 20 per cent of carbon or graphite and is mostly ferrous oxide held in place by the more corrosion resistant compounds of iron. Of all forms of corrosion, graphitic corrosion is the least objectionable since under many conditions it has considerable strength. There are many cases in which graphitized pipe has carried normal gas and water pressures for many years. This is especially true when the soil is not severely corrosive.

In certain soils which are unusually corrosive, such as man-made fills containing salts, cinders and organic matter, special precautions may be advisable. One expedient which has been used successfully to reduce corrosion is to keep the pipe out of direct contact with the corrosive soil by surrounding it during backfilling with a 6-in. layer of clean sand. The sand should be uniform in texture and free from clay balls. Under some conditions, fine crushed limestone is also an effective backfilling material, and clean loam or coarse silt has been found helpful. In general, any inert and uniform material around the pipe greatly reduces corrosion losses. Sand backfilling is effective because: (1) it increases the electrical resistivity around the pipe; (2) it creates a uniform environment and so obviates differential aeration cells; and (3) it provides a medium unfavorable to the growth of anaerobic bacteria.

Somewhat more positive protection

for the extremely corrosive soil conditions is provided by applying a coating of cement mortar or concrete. Such coatings may be applied at the foundry to protect new pipe and also may be applied in the field to prolong the useful life of badly corroded pipe.

It should be remembered that protection of cast iron pipe by sand backfilling or by concrete coating ordinarily is not necessary and should be recommended only for those rare sites where unusually severe corrosion is known to occur.

Summary

Generally speaking, soil corrosion is not a serious problem for users of cast iron pipe because the pipe furnishes its own protection. Sporadic cases of corrosion caused by unfavorable local conditions occasionally occur, but their importance should not be over-estimated. It is seldom that serious corrosion of cast iron extends throughout a wide area. When a soil survey or experience definitely indicates severe soil corrosivity, use may be made of sand backfilling or concrete coating.

1947 REPORT OF THE COMMITTEE ON QUALIFICATIONS OF SEWAGE WORKS OPERATORS

The Federation of Sewage Works Associations' standing committee on "Qualifications of Sewage Works Operators" circularized the state sanitary engineers on February 20, 1947, relative to the current status by states of operators' certification plans now in effect or under consideration. In states having plans in effect, copies of local regulations were received in most cases, and these are now on file in the headquarters office of the Federation.

The recommendation for state operators' certification plans were submitted by this committee to the Federation's membership in its report published in THIS JOURNAL, January, 1946, page 147. Appended to this report was a summary of the state plans then in effect having legal status.

Because of the interest in operators' certification plans, the committee is pleased to present below a summary of the replies received from the state sanitary engineers, whose cooperation is hereby acknowledged with thanks. Replies were received from 42 of the 48 states.

Certification plans are in effect in 12 states of which 7 have voluntary plans, and 5 required plans. Certification plans are being considered in 11 states of which 6 may be voluntary, 1 required, and 4 are undecided. Table I contains detailed data pertinent to the present status of certification activity.

Summary

This survey indicates a slow but healthy growth in the states adopting or considering a certification plan. The committee urges all states faced with a stream pollution problem (and this includes most of them) to embark on a required certification plan using as a guide the committee's suggestions for a "Model Law" as published on page 153 of THIS JOURNAL, January, 1946.

A paragraph from the committee's previous report will bear repetition and will emphasize and serve as a fitting conclusion:

"It is generally agreed that the postwar era will see an expanded program of all public works projects, one of the most important of which will be the construction of new sewage treatment plants and the modernization and enlargement of many

TABLE I.—State Sewage Plant Operators' Certification and Licensing Plans

	1	2	3	4	5	6	7	8	9		10
State	Plan in Effect	Date Started	Plan Being Considered	Voluntary or Required	Periodic Renewal of Certificate Required	Any Grandfather Clause?	Name of Agency Administering Plan	How Many Classes of Operators?	Exams. Given?		Remarks
									Oral	Written	
Alabama	No	—	No	—	—	—	—	—	—	—	A voluntary plan might be administered by Alabama Water & Sewage Assn.
Arizona	—	—	—	—	—	—	—	—	—	—	No reply received.
Arkansas	Yes	1940	Yes	Voluntary	Every 2 yr.	No	Five member board	3	—	Yes	Licensing plan under consideration to replace certification plan. Presumably would be a compulsory plan. Hope to effect licensing plan in 1 to 2 years.
California	No	—	No	—	—	—	—	—	—	—	Calif. Sewage Works Assn. has voluntary program in effect.
Colorado	—	—	—	—	—	—	—	—	—	—	No reply received.
Connecticut	Yes	1933	—	Required	No	Yes	State Dept. of Health	None	No	No	—
Delaware	No	—	No	—	—	—	—	—	—	—	—
Florida	Yes	1941	—	Voluntary	Every 3 yr.	No	Examining Board of Florida Water & Sewage Works Operators' Assn.	3	Possible	Yes	Copies of revised bylaws are available from David B. Lee, Chief Engineer, Florida State Board of Health, Jacksonville, Fla.
Georgia	Yes	1938	—	Voluntary	Every 3 yr.	No	Georgia Water & Sewage Assn.	3	No	Yes	—
Idaho	No	—	No	—	—	—	—	—	—	—	—

TABLE I (Cont.)—State Sewage Plant Operators' Certification and Licensing Plans

	1	2	3	4	5	6	7	8	9		10
State	Plan in Effect	Date Started	Plan Being Considered	Voluntary or Required	Periodic Renewal of Certificate Required	Any Grandfather Clause?	Name of Agency Administering Plan	How Many Classes of Operators?	Exams. Given?		Remarks
									Oral	Written	
Illinois	Yes	1939	—	Voluntary	Annually	For Class IV certificate only.	Illinois Sewage Works Operators' Certification Committee.	4	Yes	Yes	Copies of requirements for certification available from C. W. Klassen, Chief San. Engr., Illinois Dept. of Public Health, Springfield, Ill.
Indiana	No	—	Yes	—	—	—	—	—	—	—	Regulations for required certification of both water and sewage works operators now pending approval of Attorney General.
Iowa	—	—	—	—	—	—	—	—	—	—	No reply received.
Kansas	No	—	No	—	—	—	—	—	—	—	—
Kentucky	No	—	Yes	—	—	—	—	—	—	—	State Dept. of Health now has necessary law for certification and will put at least a voluntary plan in effect, probably next year.
Louisiana	No	—	Yes	—	—	—	—	—	—	—	May prepare a voluntary plan in 1947 under Louisiana Conference on Water Supply & Sewerage.
Maine	No	—	No	—	—	—	—	—	—	—	—
Maryland	No	—	No	—	—	—	—	—	—	—	—
Massachusetts	No	—	No	—	—	—	—	—	—	—	—

TABLE I (Cont.)—State Sewage Plant Operators' Certification and Licensing Plans

	1	2	3	4	5	6	7	8	9		10
State	Plan in Effect	Date Started	Plan Being Considered	Voluntary or Required	Periodic Renewal of Certificate Required	Any Grandfather Clause?	Name of Agency Administering Plan	How Many Classes of Operators?	Exams. Given?		Remarks
									Oral	Written	
Michigan	Yes	1940	—	Voluntary	—	Yes	State Dept. of Health	4	No	Yes	Plan is now mandatory for water works operators but not for sewage works operators. Planning to make present voluntary licensing mandatory. Proposal submitted to Legislature.
Minnesota	No	—	No	—	—	—	—	—	—	—	Certification not justified at present but will be considered in the future.
Mississippi	No	—	No	—	—	—	—	—	—	—	—
Missouri	No	—	Yes	—	—	—	—	—	—	—	Committee of Missouri Water & Sewerage Conference is preparing recommendations for voluntary plan.
Montana	No	—	No	—	—	—	—	—	—	—	—
Nebraska	No	—	Yes	—	—	—	—	—	—	—	Only discussion of plan to date.
Nevada	No	—	No	—	—	—	—	—	—	—	—
New Hampshire	No	—	No	—	—	—	—	—	—	—	—
New Jersey	Yes	1918	—	Required	Annually	Yes	State Dept. of Health	8	Yes	Yes	—
New Mexico	No	—	Yes	—	—	—	—	—	—	—	Postwar plants may justify some form of certification in 2–3 years.

TABLE I (Cont.)—State Sewage Plant Operators' Certification and Licensing Plans

	1	2	3	4	5	6	7	8	9		10
State	Plan in Effect	Date Started	Plan Being Considered	Voluntary or Required	Periodic Renewal of Certificate Required	Any Grandfather Clause?	Name of Agency Administering Plan	How Many Classes of Operators?	Exams. Given?		Remarks
									Oral	Written	
New York	Yes	1937	—	Required	No	Yes	Public Health Council, through State Dept. of Health	3	No	*	* Only in connection with Short Courses given by Department.
North Carolina	No	—	Yes	—	—	—	—	—	—	—	Some control effected by voluntary plan of certification of water works operators. Legislation for sewage works operators killed in committee hearing—1947.
North Dakota	Yes	1941	—	Voluntary	Yes	Yes	North Dakota Water & Sewage Wks. Conf.	3	No	No	Regulations not available in reprint form. Plan inactive during war.
Ohio	Yes	1937	—	Required	No	Yes	Director of Health	3	No	Yes	—
Oklahoma	No	—	Yes	—	—	—	—	—	—	—	Details of voluntary certification plan not yet worked out. Will be submitted to Okla. Water & Sewage Conference for approval.
Oregon	—	—	—	—	—	—	—	—	—	—	No reply received.
Pennsylvania	No	—	Yes	—	—	—	—	—	—	—	Approval of plant plans requires competent operating personnel. No action for certification probable for some time.
Rhode Island	No	—	No	—	—	—	—	—	—	—	—

TABLE I (Cont.)—State Sewage Plant Operators' Certification and Licensing Plans

	1	2	3	4	5	6	7	8	9		10
State	Plan in Effect	Date Started	Plan Being Considered	Voluntary or Required	Periodic Renewal of Certificate Required	Any Grandfather Clause?	Name of Agency Administering Plan	How Many Classes of Operators?	Exams. Given?		Remarks
									Oral	Written	
South Carolina	Yes	1945	—	Voluntary	Every 5 yr.	No	South Carolina Water & Sewage Works Assn.	4	No	Yes	Association action to be taken on adoption of "Model Law" proposed by Federation Committee.
South Dakota	No	—	Yes	—	—	—	—	—	—	—	Hope to start a voluntary plan within 2 years.
Tennessee	No	—	No	—	—	—	—	—	—	—	—
Texas	Yes	Voluntary 1930 Required 1945	—	Required	Yes, except for highest grade	No	Texas State Dept. of Health	4	No	Yes	Temporary certificate may be issued operator for one year only.
Utah	—	—	—	—	—	—	—	—	—	—	No reply received.
Vermont	No	—	No	—	—	—	—	—	—	—	—
Washington	No	—	Yes	—	—	—	—	—	—	—	State Health Dept. and Pacific Northwest Sec. A.W.W.A. & F.S.W.A. considering voluntary certification plan.
West Virginia	—	—	—	—	—	—	—	—	—	—	No reply received.
Wisconsin	No	—	Yes	—	—	—	—	—	—	—	Several attempts to pass legislation have been defeated in bill hearings. Action on plan now dormant.
Wyoming	No	—	No	—	—	—	—	—	—	—	Annual sewage works school held each year.

existing plants. Large expenditures for these plants will be utterly wasted funds unless the plants are competently operated. The committee therefore feels that the establishment of definite qualifications with legal status for plant operators is an important part of the postwar sanitation program, without which the entire movement may be seriously handicapped."

E. P. MOLITOR
WILLIAM A. ALLEN
LEROY W. VAN KLEECK, *Chairman*
COMMITTEE ON QUALIFICATIONS OF SEWAGE WORKS OPERATORS

TIPS AND QUIPS

"Cast Your Bread on the Waters—"

Sometime ago *The Corner* contacted several sewage works operators with the request for operation ideas, maintenance tips, time-saving gadgets, and other items which would be interesting and helpful to other sewage works men. First to come through with a contribution was Ralph Hoot, superintendent of the Fort Wayne, Ind. sewage treatment works. His reply is a perfect example of the type of material *The Corner* is seeking. It recounts the practical solution of a troublesome operating problem, a solution which also contributed appreciably to economy of plant operation.

Here is Ralph Hoot's account of how a corrosion problem was overcome by the use of ingenuity and resourcefulness.

Low-Pressure Gas Holder Corrosion

The low-pressure gas holder at the Fort Wayne, Ind. sewage treatment works is a concrete tank, 13 ft. in diameter by 8 ft. deep, with a gas capacity of 1,060 cubic feet. The gas is contained by a 3/16-in. copper-bearing steel holder which is water sealed.

When this tank was emptied for cleaning and inspection in 1944, the side walls were found to be considerably pitted due to the corrosive action of the CO_2 absorbed from the gas by the sealing water.

City water originally was used for the water seal and the piping arrangement was such that, to prevent freezing in the winter, warm make-up water for the seal could be drawn from the digester heating system. Since digester heating was a problem, no more hot water was diverted to the low-pressure gas holder water seal than was absolutely necessary. As a result, the water in the seal became corrosive from the CO_2 absorbed from the gas.

After the 1944 inspection the side walls of the holder were recemented and given a coating of Bitumastic No. 50. In addition, when the unit was again placed in service, plant effluent was used for the water seal instead of city water. In the subsequent three years there has been no corrosion or deterioration of the side walls. Weekly tests of the sealing water are made for pH, total acidity, and total alkalinity. When the acidity begins to increase, the flow of sealing water is increased until the acidity is reduced.

The use of plant effluent not only solved the gas-holder corrosion problem but also effected a decrease in the amount of city water used. In addition, due to its 50° temperature, it is no longer necessary to worry about the water seal freezing and no B.t.u.'s need be diverted from the digester heating system.

Paul Brunner, plant chemist, was primarily responsible for solving the gas-holder seal problem. About a year before the corrosion problem occurred, Brunner had suggested a plant water-piping rearrangement which would make possible the more extensive use of plant effluent of city water. The necessary changes were made and diversion of plant effluent to the low-pressure gas holder required only a simple additional change.

Brunner's pipe rearrangement suggestion not only helped solve a troublesome corrosion problem but also resulted in a $2,400 per year reduction of the plant water bill.

With the assistance of you men who are actively engaged in sewage works operation, *The Corner* can carry in each issue several practical operation ideas or maintenance suggestions, such as the one above. Your experiences do not need to be formally written but can be sent in by letter or as rough notes.

If you will help, *The Corner* can make your experiences available to other sewage works men and can bring their ideas to you.

The Battle of Germany

Seldom does a sewage treatment works have the opportunity to serve the national welfare as directly and tellingly as did the West Middlesex Main Drainage Works, Mogden, England, during the last months of the war. The following, taken from the *Institute of Sewage Purification Journal* (1945), recounts the Mogden plant's unique and direct contribution to the defeat of Germany.

"Although no official information has been given on the subject, it is now possible to disclose that the methane supplied by the Mogden plant for war purposes was used to provide the vital ingredient in the heavy incendiary bomb which was used with devastating effect in the latter stages of the bombing of Germany.

"The bomb, which weighs 30 lbs., was filled with petrol in which was dissolved a proportion of methane under pressure. On contact with the target, an intensely hot flame, 20 feet long, was immediately projected on to any object within reach. It was reported that the enemy was completely unable to extinguish the bomb or to find any effective means of combating its effects. Complete conflagrations of large areas were caused on a wide scale.

"Among the numerous towns attacked by this weapon were Stettin, Kiel, Stuttgart, Berlin and Hamburg. In a raid on Koenigsberg which was burnt down on the night of August 26th, 1944, the R.A.F. made their longest trip of all, a round flight of over 2,000 miles, when the attack was made solely with the methane bombs.

"As far as the Modgen gas compressing plant is concerned, its completion in 1942 proved to be most opportune from the national point of view, for this installation was then the only one where sufficient methane of high concentration was immediately available at a time when a supply was of the greatest urgency.

"The gas was transported across country in balloon barrage cylinders. It had to be supplied to a guaranteed specification as to the percentage of component gases and this was complied with consistently and without difficulty."

One can imagine the sense of satisfatcion with which the plant personnel received the above news. The Mogden works was repeatedly in the path of bombers. On two occasions sticks of H.E. bombs fell periously near the power station, with one stick straddling it. One night nearly a thousand incendiary bombs—half of them of the explosive type—fell right across the gas plant and power station. Two gas holders were set on fire and a large number of explosives burst inside the power station itself, all around and even on top of the engines, but without putting anything out of action.

Typically British is the restraint inherent in the comment of Mr. Townend, Engineer-in-charge of the Mogden works: "The manner in which Mogden had hit back [gave] a sense of lively satisfaction in being able to bring sewage into action for the first time by dropping sludge products on Germany itself. The man in the street would probably describe such a procedure in more unparliamentary language but at any rate it was true that every man, woman and child in the drainage district has definitely made a personal contribution."

Deep Deduction

To confound those who claim sewage works operators are masters of

exaggeration, especially when discussing their troubles, here is our entry for the "Understatement Sweepstakes" of 1947: "On several occasions during the year large sections of brass squeegee from the bottom scrapers of the settling tanks have been found at the sludge pump intakes and it is evident that the bolts holding the squeegees are failing."

Mix DDT with Caution

Although considerable experimental work has been accomplished in studying the use of DDT for filter fly control, little is known to date concerning the effect of such use of DDT on stream and fish life. A warning concerning the possible cumulative adverse effects of DDT on aquatic life has been raised by several persons cognizant of the potential damage to outlet streams inherent in the unintelligent or uncontrolled use of this compound at sewage treatment works. Nothing more than guesses or estimates, however, have been advanced as to the limiting values of DDT concentrations in filter effluents necessary to prevent damage to stream and aquatic life.

In reporting on the results of experimental work with the use of DDT for fly control in percolating filters, Tomlinson, Water Pollution Research Laboratory (Great Britain) and Jenkins, Birmingham Drainage Board (England), stated "that on some occasions the effluent from a filter immediately after the filter was treated with 1 lb. Gammexane or 5 lb. DDT per acre was distinctly toxic to trout." In the summary of their report they conclude "—there is evidence that effluents discharged from some filters at the time of treatment with the insecticides (Gammexane and DDT) were distinctly toxic to fish." While these findings are not quantitative nor conclusive they do re-emphasize the need for caution and restraint in the use of DDT for filter fly control.

The need is great for definitive work concerning the effect of DDT on the complex interrelated and interdependent biological factors controlling stream life. Until the full story is known, caution must be the watchword for all sewage works personnel utilizing DDT for filter fly control.

Information on Chlorine

The Chlorine Manual recently issued by The Chlorine Institute presents in excellent fashion information concerning the characteristics and handling of liquid chlorine.

Designed to be of value to the nontechnical person who handles chlorine and to the technician who is concerned with detailed information, the Manual is divided into four sections: Facts about Chlorine; Handling Chlorine; Employee Protection; and Data Section. The information is presented in a clear, concise manner. Style and make-up characteristics such as layout, type size, illustration, etc. are exceptionally good.

Of particular value is the comprehensive bibliography. In addition to listing references concerning the characteristics and general use of chlorine, a section is devoted to the Association of American Railroads and the Interstate Commerce Commission regulations on the handling and transportation of chlorine.

All sewage works personnel who have occasion to handle and use chlorine will find the manual a valuable source and reference guide. Copies of the manual can be obtained without charge by writing The Chlorine Institute, Inc., 50 E. 41st Street, New York 17, N. Y.

File For Future Reference

One of the first-aid measures for over-exposure to chlorine gas not in-

cluded in the new Chlorine Institute Manual is that reported in the recent issue of the *Buckeye Sludge*. Apparently the printer confounded the original copy and came up with these startling suggestions: "What to do in case exposure to (chlorine) gas caused reactions, was answered by the statement that drinking milk, fresh warm air, and a doctor as soon as possible, would bring relief from the discomfort." Milk-drinking (in emergencies) we can go along with, air-drinking lifts our eyebrows, but doctor-drinking we must see to believe!

Tips on Repacking That Stuffing Box

Sewage works operators plagued with pump-packing troubles should find some consolation in the fact that their number is legion. Stuffing box packing causes more than 25 per cent of the maintenance trouble of pump users, according to an independent survey reported in a recent issue of *The Yeomans Guard*.

Conducted by an organization not affiliated with the pump industry, the nationwide survey included both personal and written inquiries on all types and makes of pumps. While not all replies were specific concerning packing trouble many reported finding it difficult to get a packing job that would last for a reasonable length of time. In a few cases replies indicated that apparently the packing used was not suitable for the liquid pumped. Frequency of packing ranged from every three or four days to once every five years, with the average packing replacement being annually.

For the most satisfactory service, Yeomans engineers offer the following suggestions for repacking the stuffing box:

1. Remove old packing from stuffing box, taking care to withdraw the stuffing box lantern ring and the packing underneath; thoroughly clean the shaft, lantern and stuffing box.

2. For repacking, use only the packing material or its equal, originally recommended by the manufacturer for the specified service conditions. This is important since packings, like pump parts, are designed for use in handling the various media encountered, ranging from clear water through acids, alkalies, etc. If there is any doubt as to the type of packing originally used, consult the manufacturer.

3. Cut rings from spirals, unless pack already is cut into rings, making ends square cut, so that they just meet.

4. If new packing is metallic type, each ring should be dipped in heavy oil and graphite before inserting in stuffing box. Install so that direction of rotation of shaft will not be against the edge of the foil wrap.

5. Install one ring at a time, tapping it into place, being sure joints are staggered.

6. Where a lantern ring is used, install sufficient packing rings beneath it to assure locating the lantern opposite the grease or water seal connection.

7. Compress packing thoroughly, tightening gland entirely until packing feels solid in the box.

8. The gland follower should enter the stuffing box at least ¼ in. to prevent rocking of the gland. Clearance between shaft and gland should be checked with feelers to be sure shaft does not rub on gland.

9. Operate pump and adjust the gland nuts so that gland is snug, but not tight enough to bind shaft.

10. In water service conditions, the gland should leak a small amount of water at all times except when operating under a high suction lift and no fresh water connection is provided to the lantern ring.

Improved Vitrified Clay Perforated Drain Pipe

A voluntary standard for an improved design of perforated vitrified clay pipe was recently adopted by the clay products and building supply trades. Based on the war experiences of the U. S. Engineer Corps and highway officials, the new design features smaller holes scientifically placed to reduce infiltration of fine material to a minimum.

Perforations in the new design are circular and cleanly cut, ¼ in. in diameter, and arranged in rows parallel to the axis of the pipe. The perforations are approximately 3 in. center-to-center along the rows. Arranged in equal groups on either side of the vertical center line of the pipe, the total number of rows varies with the size of the pipe. Specifications for structural strength are identical for both perforated and nonperforated pipe.

Adoption of these standard specifications insures the interchangeability of all perforated clay pipe, regardless of manufacturer, and of perforated with nonperforated clay pipe.

This new perforated pipe with its improved drainage characteristics should be particularly suitable for use as slow sand filter and sludge drying bed drains.

Can You Top This?

All sewage works operators who feel their plant problems are unique are referred to the 1946–47 Annual Report of the San Diego sewage treatment plant for the most unusual maintenance problem of the year.

"In the early part of the year large numbers of seagulls swept upon the plant to scavenge on food particles in the clarifiers, causing considerable damage to the protective coating on the structural steel and mechanism.

"After many experiments this nuisance was completely eliminated by stretching single strands of monel wire twelve inches above and directly over the structural steel members and hand rails. This wire was salvaged from the vacuum filters at times of blanket changes."

Perhaps the Federation's Subcommittee on Paints and Protective Coatings already has on its agenda consideration of specifications for a seagull-proof paint! And will someone volunteer the information whether such a paint should resist mechanical abrasion—or chemical reaction?

Editorials

A PANORAMA OF THE FEDERATION

Attendance by the writer of the 19th Annual Meeting of the North Dakota Water and Sewage Works Conference last September marked his completion of the North American "circuit" in representing the Federation at Member Association meetings. About 98,600 miles have been traveled in attending 51 such meetings in the past six years, of which about 48,000 miles represents the aggregate of a round trip from the headquarters office to each of the 27 associations in the U. S. and Canada. The opportunity to meet with the constituent units of the Federation on their home grounds has been an enjoyable and enlightening experience.

Early in this visitation program it became apparent that the founders of the Federation had been wise in developing it as a union of state and regional associations, rather than as a national organization of individual members. Each constituent unit has an individuality or "personality" all its own, a vigor that can come only from self-reliance, a flexibility that permits every activity to be molded to the needs of the territory served, and an independent spirit that is typical of true democracy. Yet the bond that cements these Member Associations as a Federation is firm and real, resulting in a structure having all the facilities needed to perform such functions as are best served at the national and international levels.

One must observe the Member Associations at work to appreciate them fully. At these meetings are assembled the representatives of all of the varied interests that are concerned with stream pollution control, all contributing toward the common aim. Among the worthy activities being carried on are the sponsorship of operation short courses and other training programs, development (and, in some cases, administration) of certification and licensing plans, salary schedule investigations, research in problems of local concern, guidance and protection of municipalities where dubious or unproved services or processes are exploited, public relations campaigns, advisory guidance of state legislation, industrial waste studies, etc. These are only the more common services rendered; many other special functions have been undertaken where there has been need for action.

Although they have not been officially visited, it has also been possible through the constant exchange of correspondence to gain an appreciation of the Member Associations located elsewhere than the North American continent. The British Institute of Sewage Purification, organized in 1901 as the Association of Managers of Sewage Disposal Works, restricts its membership to those who meet high standards of training and experience and who pass a rigorous examination. Consequently, the technical programs of the Institute are at a highly scientific plane, and many important contributions have been made through them. The Institution of Sanitary Engineers (England) has broader interests, possibly comparing with the Public Health Engineering Section of APHA in the U. S. The recent Federation affiliates in Puerto Rico and Switzerland are making splendid starts in activities aimed to meet local needs.

It has been interesting to note the regional differences in policy and practice across the nation. This diversity comes from the variance in water needs and uses, climatological conditions, geological environment, industrial interests, availability of construction materials and operation chemicals, etc. In New England and New York state the protection of potable water sheds is paramount; in the Middle West agricultural interests usually govern pollution control policy; in the Far West—where "streams" are actually nonexistent most of the time—all water must be conserved and reclaimed in so far as is possible. A problem in Florida, with its flat, sandy terrain, high ground-water level, citrus canning plants, lack of native coarse aggregates (for trickling filters), lengthy ocean coast line and semi-tropical climate requires a far different approach than would be the case in Pennsylvania or Minnesota. Likewise, the differences in population densities and land uses would permit practices in New Mexico that would be entirely out of order in Connecticut. Many similar examples could be cited.

But in one respect—the kind of people who constitute the active membership of the Federation's regional segments—geography makes no difference. Everywhere there is the same constant search for knowledge as to how the diverse problems of waste treatment and disposal may be solved best and cheapest. Professional interest and enthusiasm are strong and sincere in all quarters. There is the same fascination with the task at hand wherever the Federation reaches.

And then there is the universal bond of fellowship which transcends all geographical considerations. In every one of the writer's visits, this has been manifested in a cordial welcome and a wholesome hospitality that have made every meeting a memorable occasion.

W. H. W.

Proceedings of Member Associations

CANADIAN INSTITUTE ON SEWAGE AND SANITATION

Fourteenth Annual Meeting

Niagara Falls, Ontario, Canada, October 6–8, 1947

The Canadian Institute on Sewage and Sanitation held its 14th Annual Meeting on Oct. 6–8 at the General Brock Hotel in Niagara Falls, Ontario. Registration reached an all-time high of 340.

The technical sessions consisted of a variety of subjects, all related to the field of sanitation. The meeting opened with a panel discussion on the joint administration of water and sewage works by public utilities commissions. Participants were William Davidson of Whitby, L. G. McNeice of Orillia, F. N. McCallum of Oshawa and W. M. Veitch of London, Ont.

The aspects of municipal refuse disposal were discussed. G. H. Richards of Brantford spoke on sanitary fills, B. F. Lamson of St. Catharines talked on incineration. W. M. Scott and J. A. MacGillivray presented a paper on "Ten Years' Operation of the Winnipeg Sewage Treatment Plant—Experiences and Observations."

Charles F. Rabenold, Albright & Friel, Inc., Philadelphia, Pa., presented a paper, "Architectural Treatment of Municipal Sanitary Works and Beautification of the Grounds" which was followed by a guided discussion on "Manholes and Catchbasins" led by W. S. Orr of Niagara Falls, Ont.

"Sewer Rental for Financing Sewage Works" was presented by Dr. A. E. Berry of Toronto, followed by a guided discussion on "Miscellaneous Sanitary Problems" led by R. J. Desmarais of Windsor.

At the annual banquet Dr. A. E. Berry presented the Federation's Kenneth Allen Award to William Storrie for "outstanding service in the sewage works field, as related particularly to the problems and activities of the Canadian Institute on Sewage and Sanitation."

The election of new officers in the Institute resulted as follows:

President: G. H. Richards, Brantford, Ont.

Vice-President: T. M. S. Kingston, Chatham, Ont.

Secretary-Treasurer: A. E. Berry, Toronto, Ont.

FSWA Director R. J. Desmarais' term does not expire until 1949.

A. E. BERRY,
Secretary-Treasurer

IOWA SEWAGE WORKS ASSOCIATION

1946 Annual Meeting

Cedar Rapids, Iowa, October 9–11, 1947

The 1946 Annual Meeting of the Iowa Sewage Works Association was held concurrently with the Iowa Section of the American Water Works Association at the Hotel Montrose, Cedar Rapids, Iowa, October 9–11, 1947. The opening joint-session was called to order by President C. O.

Alexander of the Sewage Works Association and Chairman John W. Pray of the Iowa Section, American Water Works Association. Mayor F. F. Hahn of Cedar Rapids welcomed those attending.

Meeting in separate session in the afternoon, the sewage works group heard and discussed the following technical papers:

"Sludge Digestion" by Don Walker, Walker Process Equipment, Inc.

"Design of Wet Wells and Grit Chambers" by D. C. Mullinex, Howard Green Engineering Co.

"Safety Measures in Sewage Plants" by S. H. Smith, Stanley Engineering Co.

"Corrosion Prevention" by Lloyd Heller, Chief Engineer, Sewage Works, Ft. Dodge, Iowa.

The joint get-acquainted smoker of Thursday night featured informal fellowship and shop-talk. Greetings from the national officers were brought by S. C. Martin, Executive Assistant, Federation of Sewage Works Associations, and President N. T. Veatch of the American Water Works Association addressed the group.

The Friday morning joint-session featured two round-table discussions. C. O. Alexander, superintendent of water and sewage treatment, Ames, and Dale Maffitt, general manager, Des Moines water works, led the discussion —"Are Salaries, Wages, Pensions, and Compensations Paid to Public Utility Employees in Line with Those of Private Utilities?" Under the leadership of Joe J. Hail, superintendent of water of Dubuque, the group discussed the care and operation of electrical equipment. J. A. Sampson, Iowa State Health Department, concluded the session with his paper, "The Effect of Recent Floods on Water Supply and Sanitation."

The joint-session Friday afternoon featured a panel discussion on the training and licensing of plant operators. Professor W. E. Galligan, Iowa State College, discussed the supervised home study courses for sewage works operators which have been developed by the certification committee of the Iowa Sewage Works Association. Consisting of five courses of twelve lessons each, these courses were prepared by Prof. Galligan and will be administered by the Engineering Extension Division of Iowa State College. They will cover completely the operation, maintenance, and administration of sewage treatment works and will be available to all Iowa sewage works operators. Enrollment fees are to be moderate and certificates will be awarded upon completion of the courses.

Paul Bolton, Iowa State Health Department, presented the certification committee report on the proposed voluntary certification plan for Iowa. The plan proposes the establishment of a Certification Board which would have representation from all interested agencies and which would: (1) supervise home study training courses; (2) classify sewage treatment works according to size and type of treatment; and (3) issue operators' certificates of competency. Such certificates would be based on education, training, experience, and demonstrated operation ability. The proposed plan follows closely the certification recommendations developed by the Operator's Qualification Committee of the Federation.

C. O. Alexander, president of the Iowa Sewage Works Association, commented on the development of certification efforts in Iowa and conducted the discussion which followed. The remainder of the afternoon was devoted to a paper on "Stream Pollution Legislation" by Paul Houser, Associate Director of the Engineering Division, Iowa State Health Department, and a round-table discussion of new devel-

opments in the water and sewage fields, which was led by D. C. Mullinex of the Howard Green Engineering Company.

The annual banquet, held jointly with the water works group, was attended by over 150 members and guests. John W. Pray presided as toastmaster. Max A. Conrad, executive secretary-treasurer of the Iowa League of Municipalities, gave the address of the evening.

The Saturday morning session of the conference was opened by George C. Ahrens' (Solitone Co., Des Moines) talk on the disposal of sludge, which included a very interesting discussion on the growing importance of organic fertilizers.

At the annual business meeting the following action was taken:

(1) The report of the Certification Plan Committee on supervised home study courses and voluntary certification was adopted.

(2) The association went on record as favoring adoption by municipalities of the sewer rental plan for sewage works financing and the placement of the sewer system and sewage treatment plant operation responsibility under one authority.

(3) Professors W. E. Galligan and Max Levine were elected life members of the association in recognition and appreciation of their long years of service to the association.

The following officers were elected for the ensuing year:

President: C. O. Alexander, Ames
Vice-President: Lloyd Heller, Ft. Dodge
Secretary-Treasurer: Leo Holtkamp, Webster City
FSWA Director: John L. Strelow, Davenport, Ia.

KENTUCKY-TENNESSEE INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

First Annual Meeting

Louisville, Kentucky, September 22–24, 1947

The First Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association was held in conjunction with the Kentucky-Tennessee Section of AWWA at the Brown Hotel, Louisville, Kentucky, on Sept. 22–24, 1947. The total registration was 133 members and guests.

F. C. Dugan, chairman of the Kentucky-Tennessee Association, presided at the sewage works section meeting. Featured papers included: "Present-Day Problems of Financing Water and Sewage Works Improvements," by Grant S. Bell, consulting engineer of Lexington, Ky.; "Historical Development of Sewage Treatment," by FSWA President George S. Russell; "Milk Waste Disposal," by Don E. Bloodgood, Professor of Sanitary Engineering at Purdue University. In addition, panel discussions were included on the program during the meeting. The first was on "Present-Day Problems of Financing Water and Sewage Works Improvements," led by G. Reynolds Watkins, assisted by J. S. Parker, Chester Lucas and John Williamson. W. J. Eldridge led a discussion on "Industrial Waste Treatment Problems," assisted by A. B. Davidson, Cecil S. Camp and S. L. Jones.

The Oct. 24 session included a paper by Maurice L. Miller, consulting engineer at Louisville on "Modern

Trends in Sewage Treatment Plant Design." A panel discussion on this subject was led by R. P. Farrell, assisted by F. C. Dugan, G. R. Watkins and James K. Latham.

Officers elected to serve during the ensuing year were:

Chairman: Julian R. Fleming, Knoxville, Tenn.

Vice-Chairman: L. S. Vance, Louisville, Ky.

Secretary-Treasurer: R. P. Farrell, Nashville, Tenn.

FSWA Director: James Ellis, Kingsport, Tenn.

All those registered for the meeting were invited to a luncheon at the Louisville Water Filtration Plant, which was followed by an inspection tour of the property. Other entertainment for the meeting included a special dinner and entertainment on Oct. 22, and the annual dinner-dance in the evening of October 23.

R. P. FARRELL,
Secretary-Treasurer

NEW ENGLAND SEWAGE WORKS ASSOCIATION

Eighteenth Annual Meeting

New London, Connecticut, September 10, 1947

The Eighteenth Annual Meeting of the New England Sewage Works Association was held September 10, 1947, at Ocean Beach Park, municipally operated by the city of New London, Connecticut, with 116 members and guests in attendance. President Thomas R. Camp presided.

The morning session included the following technical papers:

"Boston Metropolitan Sewerage System, Experience with and Comments on," by Thomas A. Berrigan, Chief Engineer, Sewerage Division, Metropolitan District Commission, Boston.

"Industrial Wastes Problems in Stream Pollution Abatement," by William S. Wise, Chief Engineer, Conn. State Water Commission.

"New London Sewage Treatment Plant, Design and Operation," by N. S. Holroyd of Keis & Holroyd, Troy, N. Y.

Following a catered luncheon, Worthen H. Taylor of the Mass. Department of Public Health told of his experiences as an officer in the Sanitary Corps, U. S. Army, under the title, "A Sanitarian in Insanitary Japan." The remainder of the afternoon was devoted to an inspection of the New London Sewage Treatment Plant and the municipal refuse incinerator.

Officers elected for 1948 were:

President: LeRoy W. Van Kleeck, Hartford, Conn.

First Vice-President: Walter H. Brown, Jr., Cranston, R. I.

Second Vice-President: Ralph W. Horne, Boston, Mass.

Directors: Charles J. Hammann, Providence, R. I.; E. A. Locke, Hartford, Conn.; John D. McDonald, Springfield, Mass.

Secretary-Treasurer: Walter E. Merrill, Boston, Mass.

WALTER E. MERRILL,
Secretary-Treasurer

PENNSYLVANIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

Twenty-First Annual Meeting

State College, Pennsylvania, October 25–27, 1947

The Pennsylvania Sewage Works Association held its 21st Annual Meeting in conjunction with the Pennsylvania Water Works Operators' Association at State College on Aug. 25–27, 1947.

Among the interesting and informative papers presented pertaining to the sewage works field were:

"Sludge Digestion and Scum Disposal" by R. S. Rankin of The Dorr Company of New York City. The discussor was J. J. Gilbert of the Link Belt Company of Philadelphia.

"High Rate Filter Performance" by F. W. Mohlman of the Sanitary District of Chicago was discussed by W. A. Hardenbergh, Editor of *Public Works* Magazine, New York City.

"Chlorination of Sewage" by Noel S. Chamberlin, sanitary chemist of the Wallace & Tiernan Company of Newark, N. J. Mr. Chamberlin's paper was discussed by Gordon J. Wiest, chemist, Albright & Friel, Inc., Philadelphia, and George Benbury of the Pennsylvania Salt Manufacturing Company of Philadelphia.

"Elements of Electricity and Maintenance of Electrical Equipment" by J. J. Monroe and H. W. Yerkes, both of the Westinghouse Corporation.

The August 27 session commenced with an operators' forum led by Robert M. Bolenius, chemist of the city of Lancaster, Pa.

"Measurement and Control of Sewage Plant and Process Efficiency by Oxidation-Reduction Potential" was given by John W. Hood, superintendent of the Ridgewood, N. J., sewage treatment plant. Discussors were Gerard A. Rohlich of the University of Wisconsin at Madison and L. L. Langford of the Pacific-Flush Tank Company of New York City.

"Waste Treatment Problems from the Viewpoint of Industry" was presented by W. B. Hart of the Atlantic Refining Company in Philadelphia. F. B. Milligan of the Pennsylvania Department of Health at Harrisburg discussed this paper.

An industrial wastes symposium concluded the technical sessions of the meeting. Roy F. Weston of the Atlantic Refining Company in Philadelphia led the discussions. "Pennsylvania's Water Resources and Water Uses" was presented by Dr. Jack Graham, U. S. Geological Survey. "The Influence of Industrial Stream Pollution on Aquatic Life" was discussed by Dr. Gordon L. Trembley, chief aquatic biologist on the Pennsylvania Board of Fish Commissioners. W. B. Hart in charge of pollution abatement activities in the Atlantic Refining Company presented "The History and Development of Pollution Abatement Legislation in Pennsylvania." J. R. Hoffert, assistant chief engineer of the Pennsylvania Department of Health, spoke on "Administrative Policies and Problems as Applied to Industrial Waste Disposal in Pennsylvania."

At the annual banquet, FSWA President Francis S. Friel spoke on "The Expanding Federation." James Stokley of the General Electric Company gave a lecture and demonstration on "Science Remakes the World." One of his outstanding demonstrations was the vividly pictured explosion and activity of an atomic bomb.

At the annual business meeting the

name of the Pennsylvania Sewage Works Association was changed by unanimous vote to the Pennsylvania Sewage and Industrial Wastes Association. New officers elected to serve during the 1947–48 term were:

President: N. G. Young, Phoenixville
1st Vice-President: C. H. Young, Meadville
2nd Vice-President: E. T. Roetman, Philadelphia
Secretary-Treasurer: B. S. Bush, Wilkes-Barre

FSWA Director L. D. Matter will serve through 1949.

The membership of the association voted favoring sponsorship of a five day Short Course School at Pennsylvania State College to be held at annual conference time. At the Executive Meeting during November a permanent Short Course Committee will be appointed.

B. S. BUSH,
Secretary-Treasurer

ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION

Eleventh Annual Meeting

Denver, Colorado, September 24, 1947

The Eleventh Annual Meeting of the Rocky Mountain Sewage Works Association was held at the Cosmopolitan Hotel, Denver, Colorado, on September 24, 1947. Following registration, Robert Streeter, consulting engineer, Casper, Wyoming, presented a paper on "Enlarging Sewage Plants for Increased Capacity," which discussed the various methods available for increasing the efficiency and capacity of sewage treatment units. He emphasized that only after all such possibilities have been explored should additional plant capacity be provided by new construction. Warren H. Booker, Dept. of Public Health, Santa Fe, N. M., discussed Mr. Streeter's remarks.

Two additional technical papers were presented at the morning session: "Operating Problems in New Mexico" by Charles Caldwell, Dir., Dept. of Public Health, Santa Fe, New Mexico, and "Advance in Digestion" by Dana Kepner, representing the Pacific Flush Tank Company.

At the annual business luncheon reports were received from the secretary-treasurer, the nominating committee, the committee on licensing, and the association's representative on the Federation Board of Control. Director Leonard gave a very interesting account of the Federation meeting in San Francisco and of the Board of Control sessions. Particularly pertinent was the news of the tentative selection of Denver for the 1950 Federation meeting.

Commenting on the report of licensing committee, Mr. Riepe stated that Colorado was planning for voluntary certification, as it appeared too complicated to develop a license standard for all the different classes of permits which would be required. Mr. Williams indicated that Wyoming operators felt similarly about the problem and Mr. Caldwell related that New Mexico did not believe in licensing operators for the reason that it would work too much of a hardship on the towns in the state. No recommendations were presented by the committee.

The business session concluded with the election of the following officers for 1948:

President: H. G. Watson, Cheyenne, Wyoming

Vice-President: B. V. Howe, Denver, Colorado

Secretary-Treasurer: G. E. Riepe, Denver, Colorado

The afternoon session was opened by G. O. Wilson's (The Dorr Company) talk on "Present Trends in Sewage Disposal." An account of operation problems at the Colorado Springs sewage treatment plant, by Superintendent John M. Frederick, served as an excellent introduction for the following round-table discussion on plant operation, which was conducted by H. G. Watson, City Engineer of Cheyenne, Wyoming. One of the many interesting operation problems discussed pertained to settling tank influent baffles. The possibility of reducing digester heating troubles by placement of the heating coils within digester walls was raised and evoked considerable comment. The meeting was adjourned following a summation of the operation items considered during the round-table discussion.

CARROLL H. COBERLY,
Secretary-Treasurer

WEST VIRGINIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

First Annual Meeting

Bluefield, West Virginia, October 1–2, 1947

The First Annual Meeting of the West Virginia Sewage and Industrial Wastes Association was held at Bluefield, West Virginia, on October 1 and 2, 1947. A total of 97 members and guests were registered. Fifty-three of eighty-nine members of the association attended the meeting giving an attendance percentage of 59.5.

The conference was opened with an address of welcome by A. Harry Vest, mayor of Bluefield, and a response was given by President Kyle L. Bruce, superintendent of the Bluefield Sanitary Board.

The technical program on October 1 started with an elementary symposium on sewage treatment. As this was the first technical meeting of the association and the majority of the members are relatively new in the field, the program committee chose to present an elementary symposium as an introduction to future technical discussions. The members of the symposium presented the purposes and objectives of treatment, illustrated descriptions of various units, basic design, and expected results. H. W. Speiden, head of the Department of Civil Engineering at the West Virginia University, introduced the symposium giving a history of sewage treatment, a description of sewage, and fundamental concepts of treatment. R. G. McCall, associate engineer at the West Virginia Health Department, gave an illustrated description of secondary sewage treatment including trickling filters, activated sludge, chemical precipitation, sand filters and other methods. "Chlorination of Sewage" was discussed by J. P. Kavanagh, Wallace and Tiernan engineer at Charleston, West Virginia. The symposium was concluded with a lively discussion with the symposium authors serving as a board of experts. The program for the day was concluded by an informative paper entitled, "Tannery Wastes Treatment" by Howard Reuning of the Keystone Tanning and Glue Company of Ridgway, Pa.

During the evening, a buffet supper and entertainment was provided by courtesy of the West Virginia

Water Service Company. This gathering gave the members an opportunity to meet water works personnel whose meeting started the next day.

The program on October 2 was started with a color film, "The Treatment of Some Chemical Wastes" by courtesy of the Dow Chemical Company of Midland, Michigan. The commentary on this film was read by H. K. Gidley, engineer of the West Virginia Health Department.

K. S. Watson, engineer of the West Virginia State Water Commission, gave a timely paper on "Cooperative Solutions of Stream Pollution Problems" in which the state agencies' cooperative program was explained.

"Treatment and Recovery of Phenol in By-Product Coke Plants" was presented by P. D. Simmons, chemist with the Weirton Steel Company of Weirton, West Virginia.

Walter N. Stancati, Foxboro Meter Company of Pittsburgh, presented "Flow Measurements," a timely paper since industry in West Virginia is now conducting extensive studies of their wastes.

"Ten Years' Operation of Bluefield's Sewage Treatment Plants" by Marvin Williams, chemist of the Bluefield Sanitary Board, served as an introduction to the field trip and was an outstanding example of the importance of good records and operation.

The afternoon inspection trips were made to an exhibition coal mine at Pocahontas, Virginia, through the courtesy of the Pocahontas Fuel Company and a conducted tour of Bluefield's sewage treatment plant.

The annual banquet was held in conjunction with the West Virginia Section of the American Water Works Association with Mike Siebert, Neptune Meter Company of Richmond, Virginia, serving as toastmaster.

At the annual business meeting the following officers were elected for the ensuing year:

President: P. D. Simmons, Weirton
First Vice-President: J. E. Settle, Charleston
Second Vice-President: Edward Shroyer, Fairmont
Secretary-Treasurer: R. G. McCall, Charleston

The term of K. S. Watson as FSWA Director continues until 1950.

R. G. McCall,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
New York State Sewage Works Association	Hotel Pennsylvania, New York, N. Y.	Jan. 23–24, 1948
Texas Sewage Works Section	Texas A. & M. College, College Station, Tex.	Feb. 8–12, 1948
Kansas Water and Sewage Works Association	Hotel Broadview, Wichita, Kan.	Mar. 11–12, 1948
New Jersey Sewage Works Association	Hotel Stacy Trent, Trenton, N. J.	Mar. 10–12, 1948
Arizona Sewage & Water Works Association	New Dominion Hotel, Globe, Ariz.	Apr. 2–4, 1948
Montana Sewage Works Association	City Auditorium, Livingston, Mont.	Apr. 8, 1948
Arkansas Water & Sewage Conference	University of Ark. Campus, Fayetteville, Ark.	Apr. 12–14, 1948
New England Sewage Works Association	Marlborough Country Club, Marlborough, Mass.	May 12, 1948
Pacific Northwest Sewage Works Association	Hotel Boise, Boise, Idaho	May 12, 1948
Florida Sewage Works Association	University of Florida, Gainesville, Fla.	June 7–12, 1948
Central States Sewage Works Association	Milwaukee, Wis.	June 18–19, 1948
Pennsylvania Sewage Works Association	Nittany Lion Inn, State College, Pa.	Aug. 25–27, 1948
Arizona Fall Conference	Phoenix, Ariz.	Oct. 15–16, 1948
Federation of Sewage Works Associations	**Statler Hotel, Detroit, Mich.**	**Oct. 18–21, 1948**
Michigan Sewage Works Association	Statler Hotel, Detroit, Mich.	Oct. 18–21, 1948

Federation Affairs

ANNUAL MEETING OF BOARD OF CONTROL HELD AT PHILADELPHIA

The Twentieth Annual Meeting of the Board of Control of the Federation was held at the Philadelphia Country Club, Philadelphia, Pa., on October 10, 1947.

President George S. Russell of St. Louis, Mo., and Vice-President V. M. Ehlers were inducted into office at the opening of the session, and Mr. Russell presided thereafter. Other officers and directors in attendance were Past President Francis S. Friel, C. C. Larson, L. M. Fisher, R. E. Fuhrman, K. L. Chrysler, L. W. Van Kleeck, P. N. Daniels, L. D. Matter, L. L. Hedgepeth, K. S. Watson, W. J. Orchard, Dr. Willem Rudolfs and Executive Secretary-Editor W. H. Wisely.

Others in attendance, to whom proxies had been assigned, were Past President C. A. Emerson, J. W. Van Atta, E. M. Jones, G. E. Symons, G. A. Elias, F. C. Dugan, L. H. Enslow, R. C. Beckett, H. E. Moses, F. W. Gilcreas and Karl M. Mann.

The session was a productive one, with several recommendations of the 1947 Board at San Francisco being confirmed, one action at the July meeting being rescinded, and a number of new directives being initiated. A summary of the principal actions taken is given below.

Friel Honored

The first official act of the new Board was to adopt a resolution of appreciation to Francis S. Friel, retiring President, for his valiant service and stimulating leadership during his term of office just ended. This recognition was tendered unanimously by rising vote.

Mohlman and Wisely Reappointed

Confirming the recommendation of the 1947 Board, approval was given the reappointments of Dr. F. W. Mohlman and of W. H. Wisely as Advisory Editor and Executive Secretary-Editor, respectively. Both appointments are for two-year terms covering the fiscal (calendar) years of 1948 and 1949.

1947–48 Committees Appointed

The following committee appointments for the year 1947–48 were submitted by President Russell and approved by the Board:

Executive: George S. Russell, *Chairman;* A. E. Paxton, L. D. Matter, Frank S. Taylor, J. L. Strelow.

General Policy: F. S. Friel, *Chairman;* A. H. Niles, John R. Downes, Dana E. Kepner, R. E. Fuhrman, K. L. Chrysler, H. M. Rath.

Publications: C. C. Larson, *Chairman;* F. W. Mohlman, W. H. Wisely, F. W. Gilcreas, Rolf Eliassen, Carl E. Green, Harry J. Krum.

Organization: Earnest Boyce, *Chairman;* C. R. Compton, R. H. Suttie.

Sewage Works Practice: Morris M. Cohn, *Chairman;* W. H. Wisely, F. W. Mohlman, C. E. Keefer, G. P. Edwards, A. H. Niles, Langdon Pearse, L. W. Van Kleeck, F. W. Gilcreas, R. F. Brown, K. V. Hill, D. E. Bloodgood, Willem Rudolfs, F. M. Veatch, Norval E. Anderson, K. L. Mick, C. W. Klassen, John W. Hood.

Research: Willem Rudolfs, *Chairman;* H. E. Babbitt, D. E. Bloodgood, G. P. Edwards, H. A. Faber, A. L. Genter, H. Heukelekian, H. J. Miles, F. W. Mohlman, C. C. Ruchhoft, L. R. Setter, L. W. Van Kleeck.

Nomenclature: C. J. Velz, *Chairman;* C. A. Emerson, C. E. Keefer.

Standard Methods: W. D. Hatfield, *Chairman;* G. E. Symons, S. E. Coburn, A. J. Fischer, G. P. Edwards, E. W. Moore, D. E. Bloodgood, F. W. Gilcreas, Keeno Fraschina, W. S. Mahlie, M. Starr Nichols, Richard Pomeroy, C. C. Ruchhoft, Willem Rudolfs, H. Heukelekian, R. D. Hoak, Roy F. Weston.

Water and Sewage Works Development: C. A. Emerson, G. J. Schroepfer.

Meeting Place: George S. Russell, *Chairman;* V. M. Ehlers, F. S. Friel, W. H. Wisely, Daniel J. Saunders, A. E. Paxton, A. T. Clark.

Publicity and Attendance: L. H. Enslow, *Chairman;* M. M. Cohn, E. J. Cleary, Wm. S. Foster, A. Prescott Folwell, J. P. Russell, J. A. Daly.

Convention Management: W. J. Orchard, *Chairman;* W. F. Shephard, W. H. Wisely, A. T. Clark, A. E. Paxton.

Awards: G. M. Ridenour, *Chairman;* H. W. Stretter, Harold B. Gotaas.

Operation Reports: A. F. Dappert, *Chairman;* G. A. Hall, W. A. Allen, Gordon J. Weist.

Finance Advisory: W. J. Orchard, *Chairman;* F. S. Friel, George S. Russell.

Industrial Wastes: F. W. Mohlman, *Chairman;* W. B. Hart, D. E. Bloodgood, H. W. Gehm, L. F. Oeming, Wm. S. Wise.

Legislative Analysis: Ralph E. Fuhrman, *Chairman;* Earnest Boyce, L. D. Matter, David B. Lee, L. J. Fontenelli, V. M. Ehlers, L. F. Warrick, R. L. Winget.

Honorary Membership: A. M. Rawn, *Chairman;* A. E. Berry, J. K. Hoskins, F. S. Friel, George S. Russell.

Nominating: G. J. Schroepfer, *Chairman;* A. E. Berry, J. K. Hoskins, F. S. Friel, A. M. Rawn.

Quarter Century Operators Club: Frank W. Jones, *Chairman;* Stuart E. Coburn, Harold W. Streeter.

Operator's Qualifications: L. W. Van Kleeck, *Chairman;* Wm. A. Allen, E. P. Molitor.

Deficit Budget Adopted

Confronted with an increase of more than 13 per cent in the cost of printing and mailing publications, and the desirability of appropriating funds toward the travel expenses of the President and Vice-President in their visitation of Member Association meetings, the Board adopted a budget for the 1948 fiscal year in which anticipated expenses exceed receipts by $3,000.

The detailed 1948 budget is as follows:

Receipts

Membership dues		
Active	$12,000	
Corporate	350	
Associate	1,500	
Non-member subscriptions	2,600	
Advertising (net)	20,000	
Sale of reprints and single copies	900	
WSWMA contribution	5,000	
Miscellaneous income	500	
Total Receipts		$42,850

Disbursements

JOURNAL printing and mailing	$20,000	
Executive Secretary—salary	8,000	
Office salaries	10,600	
Office expense	1,400	
Travel expense	1,800	
Office rent	900	
Editorial expense	250	
Officers' travel	1,500	
Committee expense	200	
Administration expense	300	
Awards	600	
Contingencies	300	
Total Disbursements		$45,850
Deficit (to be made up from surplus		$ 3,000

Authorization was given the Executive Committee to transfer up to $5,000 from surplus to the Manual of Practice Revolving Fund, if such action becomes necessary during the year to finance the production of new manuals.

Constitution and Bylaws Committee Created

After six years of administration of the Federation under the constitution and bylaws as amended in 1941, it is apparent that some further revisions are advisable, particularly in the clarifying of certain sections. Toward this end the Board created a special Committee on Constitution and Bylaws, which committee will review the existing instrument and make recommendations covering desirable amendments. The committee will comprise C. A. Emerson as chairman, with F. S. Friel, W. J. Orchard, F. W. Gilcreas and President Russell.

Action was taken to initiate an immediate amendment to Section 1 of Article VI of the Bylaws, which now provides for the Executive Committee to consist of the President and four Directors. The amendment, to be acted upon by letter ballot, would expand the committee to seven members by including the Vice-President and Past President as *ex-officio* appointees.

Future Convention Sites Considered

Confirmation of Denver as the location of the 1950 Annual Meeting was deferred pending still further consideration of hotel facilities and of the adequacy of member-

ship in the Denver area to staff the several convention management committees.

A formal invitation was received by the Board from the Maryland-Delaware Water and Sewerage Association for the Federation to meet in Washington, D. C., in 1950 or 1951.

1947 Hatfield Awards

Upon the recommendation of the Committee on Operation Reports, the Board approved the annual reports of the Minneapolis-St. Paul Sanitary District (for plants serving populations over 100,000), of the city of New Britain, Conn. (for plants serving 10,000 to 100,000) and of the city of Belvidere, Ill. (for plants serving less than 10,000 population) as winners of the 1947 William D. Hatfield Award competition. Those responsible for the preparation of these reports and who will receive certificates betokening the award are George J. Schroepfer and Warren H. Sleeger (Minneapolis-St. Paul), John R. Szymanski (New Britain), and F. E. Peterson (Belvidere).

The Minneapolis-St. Paul and Belvidere reports were entries of the Central States Sewage Works Association, and the New Britain report was entered by the New England Sewage Works Association.

1947 Membership Prizes

On the basis of the Executive Secretary's membership report the Board awarded $100 prizes to the Institute of Sewage Purification (Great Britain) and to the Arkansas Water and Sewage Conference, as the winners of the 1947 membership contest. The ISP recorded a numerical increase of 66 members during the contest to lead all other Member Associations in this respect. By increasing in size from 4 to 33 members in the year ended September 30, 1947, the Arkansas conference established a gain of 725 per cent, winning this prize by a wide margin.

Operation Salary Studies Urged

The Board action at San Francisco to expand the functions of the Committee on Operators' Qualifications to include studies and recommendations on plant operation salary schedules was rescinded at the Philadelphia session. The abandonment of this activity at the national level was considered advisable because of the wide variation in wage scales throughout the U. S.

There was due appreciation of the need for salary studies, however, and the Board moved to encourage committee activity in all Member Associations along these lines. Special committees in the California and New England units of the Federation have already been productive in developing recommended salary schedules for sewage works operation personnel.

Swiss Member Association Approved

Subject to the completion of formal affiliation requirements, the Swiss Association of Water and Sewage Professionals was extended immediate membership privileges in the Federation as a Member Association. The Swiss organization will become the thirty-third constituent unit of the Federation, and the sixth one located outside of the continental limits of the U. S.

BRITISH AND ARKANSAS ASSOCIATIONS WIN 1947 MEMBERSHIP PRIZES

For the first time since their inception, one of the membership prizes went overseas—to the Institute of Sewage Purification of England. By adding a net gain of 66 new members since September, 1946, the Institute won handily the $100 cash membership prize for the greatest numerical increase. While this year's membership contest was not as spirited as that of last year, when the winner was decided on the last day, several member associations made creditable net gains. The Michigan Association, with a net gain of 56, won the runner-up spot and was followed by Iowa with 39 new members. Arkansas increased its membership by 29; Georgia added 28; and the Canadian Institute, winner of the 1945 and 1946 numerical contests, showed another excellent gain of 26 new members.

By enlarging its membership from 4 to 33 during the 1947 contest, the Arkansas Sewage Works Association had little difficulty in winning the $100 cash prize for the greatest percentage membership increase since September, 1947, with a percentage gain of 725. Other member associations which made creditable percentage gains were: Iowa with 95.1 per cent, Georgia—56 per cent, Institute of Sewage Purification—54.5 per cent, and Michigan —41.2 per cent.

The four new member associations of the Federation, ineligible to participate in the contests this year, started with exceptionally large charter memberships. The Virginia Association led this group with 61 members, followed by West Virginia with 45, Kentucky-Tennessee with 44, and Puerto Rico with 36 charter members.

Only eight member associations failed to show an increase in membership for the contest year. There is a good possibility that 1947 will be the Federation's greatest membership year. At this writing (November 15, 1947) the aggregate membership of member associations totals 4,351, a net gain of 648 for the first 10½ months of this year. In 1929, the first full year of the existence of the Federation, 686 members were enrolled, which is the present record. The member association secretaries and membership committees are to be commended for their fine efforts during the contest year.

Reviews and Abstracts*

Dewatering of Sewage Sludge by Coagulation and Vacuum Filtration.* Part II—Experiments with a Semi-scale Dorr-Oliver Vacuum Filter. By J. M. Wishart, C. Jepson and L. Klein. *Institute of Sewage Purification* (April 30, 1947).

Experiments were carried out with a semi-scale Dorr-Oliver vacuum filter at the main works of the Manchester Corporation Rivers Department at Davyhulme to study the economics of vacuum filtration of various types of sewage sludge. The filter was 5.25 ft. in diameter and 2 ft. wide with an area of 31 sq. ft. A wool flannel filter cloth seemed satisfactory and $FeCl_3$ was the best conditioning agent. Adjustment of the $FeCl_3$ dose was made by observation of the pH and the ferric iron content of the filtrate. A pH of 3.4 to 3.6 and ferric iron content of 30 to 35 p.p.m. seemed optimum, although in practice a pH range of 3.4 to 4.0 and 35 to 50 p.p.m. of ferric iron were satisfactory.

Activated sludge yielded a filter cake containing 87 to 90 per cent moisture, much higher than the 80 to 83 per cent obtained in America. Furthermore, an average of about 13 per cent $FeCl_3$ (dry basis) was required as compared with 8 to 10 per cent in American practice. The cake yield was variable but averaged 1.3 lb. of dry sludge per sq. ft. per hour. The high chemical consumption and moisture content may be caused by the relatively high volatile content and by the large proportion (30 per cent) of industrial waste. Because of differences in sedimentation practice, English sludges also seem more colloidal and less gritty than American sludges.

Better results were obtained with mixtures of activated and primary sludge than with activated sludge alone. The cake moisture content of 73 to 85 per cent and the $FeCl_3$ dosage of 6 to 14 per cent varied with the relative proportion of the two sludges. The sludge yield varied from 0.5 to 2.4 lb. per sq. ft. per hour.

Aeration of the sludges (activated or mixed) for about two hours prior to conditioning greatly reduced the ferric chloride needed. The improvement seemed to be due to the reduction in alkalinity of the sludge liquor and to the oxidation of reducing substances formed when the sludge is stored. Continuous aeration for 24 hours or longer before conditioning with $FeCl_3$ was harmful as the sludge floc seemed to be dispersed.

Elutriation of activated sludge and mixtures of activated and primary sludges to reduce the $FeCl_3$ dose was not as satisfactory as the two-hour aeration. In digested sludge, elutriation with 9 volumes of tap water reduced the $FeCl_3$ required to about 4 to 8 per cent and yielded a cake containing about 70 per cent moisture at a rate of 2.0 to 3.6 lb. dry solids per sq. ft. per hour.

Vacuum filtration of sludge depends to some extent on the weather. After a heavy rain, less $FeCl_3$ is needed and the cake output increases. In long periods of dry weather, particularly during the summer, the $FeCl_3$ demand increases and the yield decreases. The filtrates generally contained less than 100 to 150 p.p.m. suspended solids but the B.O.D. varied from about 125 to 900 p.p.m. The ferrous iron content varied from about 125 to 1,250 p.p.m. When exposed to air the sludge cake could be dried in a week or more. By infrared radiation it can be dried in 15 to 20 min., but this is expensive.

* A preprint. For abstract of Part I (Laboratory Experiments) see This Journal, 18, 4, 765 (July, 1946).

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

Analysis of the dried cake is as follows:

	Per Cent—Dry Basis			
	Nitrogen N	Phosphorus P_2O_5	Potassium K_2O	Grease $CHCl_3$
Primary Sludge *	3.1	2.3	Trace	30.3
Activated Sludge	6.0	3.8	0.4	7.5
Elutriated Digested Sludge	3.5	3.8	0.06	8.7

* Contained some activated sludge.

Partly because of the high cost of $FeCl_3$ ($100 per ton, dry basis), the total cost per ton of filtering and drying various sludges would be about $33 for activated, $18 for mixtures of primary and activated, and $14 for thickened digested sludge. The cost of producing a fertilizer containing 15 per cent moisture would be at least $14 per ton.

Most of the sludge produced in Manchester is disposed of by dumping into the sea. Prewar costs were about $2.20 per dry ton. Present day costs are much higher because of the general rise in prices and because of the loss of the sludge steamer by enemy action in 1941. Digested sludge of similar density to that used in the experiments can be disposed of at sea for about $7 per dry ton.

GAIL P. EDWARDS

Byproducts from Sewage Sludge. By W. H. HILLIER. *The Surveyor,* **106**, 346 (July 4, 1947).

Trade wastes, chiefly from wool scouring plants and dyeworks, constitute about one-half of the flow to the Esholt works of the Bradford Corporation. Because of the wool scouring wastes the sewage is very greasy and difficult to treat. Sulfuric acid is mixed with the sewage, after it has passed through the coarse screens and detritus tanks, in such quantities as to give an acid reaction of 100 p.p.m. to methyl orange. The bulk of the grease is deposited in the settling tanks and the tank effluent is passed through trickling filters, humus tanks, and a clarification lake.

Sludge drawn from the settling tanks is acid-conditioned, heat-treated, and dewatered by means of filter presses. The greater part of the grease is released by this process. A great deal of research has been done on sewage treatment and recovery of byproducts. Digestion of sludge was considered but found impractical at Esholt. It appeared that any practical method of sludge disposal must include grease recovery, and this has been done for several years with satisfactory results. Sales of the byproducts, grease and organic fertilizer, have met operating expenses and have partly paid interest and sinking fund charges each of the past 6 years.

In 1946–47 the cost of sludge disposal, starting with the mixed sludges at the sludge screen house, was $490,096. This includes interest and sinking fund charges in the amount of $208,856. Income was $84,188 from fertilizer sales and $510,696 from sale of grease. The tonnage of sludge handled was 146,180 with an average moisture content of 85.71 per cent. It was handled at a cost of $3.35 per ton.

Investigations of sludge pressing have shown that it is impossible to reduce the grease in the press cake below 16 per cent of the dry weight. This is of concern with the present demand for grease. Laboratory work has been carried on with a method of solvent extraction. The process is now under examination from an engineering and economic standpoint.

Studies are to be made on the utilization of coarse screenings and mineral salts in the final effluent. Screenings and the organic fertilizer are to be composted with vegetable and other organic refuse and compared upon application to the land. The two composted materials will be compared to artificial fertilizers and to the organic fertilizer as made at the plant.

Recovery of mineral salts from the final effluent is to be tried through the agency of suitable water plants grown in the clarification lake. (Figures for costs and revenue were computed on the basis of $4.00 per English pound.)

T. L. HERRICK

Recovery of Byproducts at Bradford Sewage Works. DISCUSSIONS. *The Surveyor,* **106**, 481–482 (Sept. 12, 1947).

In reply to discussions Mr. Hillier stated that he was not advocating a

scheme of grease recovery at all plants. From a national viewpoint such a large scale recovery would have much to commend it. At Bradford the sludge contains 45 per cent grease, dry basis, and it is felt that recovery might be considered at any plant when the percentage of grease does not average less than 25 per cent.

Three methods of extraction of grease from the press cake by means of solvents were investigated in the laboratory. The first involved stirring large volumes of solvent with sludge cake, followed by settling and decantation. A rather wet cake with a small percentage of grease remained. The second method involved mastication of the wet cake with alcohol, followed by filtration and recovery of the alcohol-water mixture. The solvent could then be used to remove all of the grease, leaving a comparatively dry residue. The last method utilized azeotropic properties wherein a solvent mixture, on boiling with the cake, would distill off and carry away a considerable portion of the water. This was carried on until the cake was sufficiently dewatered to allow passage of the solvent through a bed of it.

Specialized byproducts were prepared for sale as it had been found at times in the past that it was difficult to dispose of the grease in the crude form.

Drying oils, for use with paints along with linseed oil, have also been recovered at Esholt. It is felt that this material will still have a market after linseed oil becomes readily available.

The crude wool suds are the only wastes for which a charge is made in Bradford. The charge is 6d (about 10¢) per 1,000 gallons (Imp.). No charge is made if the manufacturer has a grease recovery plant.

The low phosphate content of the sludge fertilizer had been noted. The low content is due to the acid and heat treatment given the sludge. This treatment breaks down the insoluble lime phosphates to form soluble phosphoric acid which is lost in the effluent. It is hoped that the phosphates and potash dissolved in the effluent can be recovered by plant life in the clarification lake, and the plants composted to make a fertilizer.

T. L. HERRICK

West Middlesex Main Drainage: Operating Experiences. BY C. B. TOWNEND AND W. T. LOCKETT. *The Surveyor*, **106**, 342 (July 4, 1947).

The West Middlesex project was formed to serve 15 local districts. Sewage formerly treated at 28 plants is now treated at the Mogden works. Sewage was first diverted to the new plant in December, 1935.

The main sewerage system was designed for an ultimate population of 2,000,000. About 70 per cent of the flow enters the plant by gravity and the remainder is pumped, the lift being about 52 feet. The sewer system has a capacity of 600 m.g.d. and while not designed for storm relief, it may be utilized if desired to relieve flooding in certain areas by overflowing river water into the sewer when capacity is available.

The Mogden works was designed for a population of 1,000,000. Additional units now built are the first portion of the intended duplication of the works. However, planning restrictions on the growth of greater London will prevent the ultimate design figure of 2,000,000 being reached.

The activated sludge process has worked well at Mogden and has never failed to produce a high-grade effluent. Digested sludge is pumped to a site about 7 miles away where drying beds are provided. Sludge gas is utilized in gas engines.

T. L. HERRICK

Operating Experiences at West Middlesex Main Drainage Works. DISCUSSIONS. *The Surveyor*, **106**, 507–509 (Sept. 26, 1947).

Mr. Lockett, chief chemist of the Mogden Works, discussed the B.O.D. test and suggested that it might well be time for a complete revision of the test. It has been observed by others that at times effluents are satisfactory except for the 5-day B.O.D., and that the high results have been shown to be due to oxidation of ammonia and nitrite during the incubation period. Also results vary from time-to-time because of differences in the dilution water. Perhaps the general adaption of a standard dilution water would become necessary.

At Mogden it is obligatory that the sewage be given a high degree of treatment. The plant is located in a built-up area and it was necessary that everything possible be done to keep odors to an absolute minimum. It was felt that it was necessary to produce an effluent containing nitrates. Such an effluent has been produced with an air consumption of 1.14 cu. ft. per gallon (Imp.). The average detention period in the aeration tanks was 7.38 hours. Even were power purchased at Mogden it is felt that nitrification would be desirable. However, since power is produced from sludge gas there is no objection from the standpoint of cost.

In determining quantities of industrial wastes, means for direct measurement were installed where large volumes, or wastes difficult to treat, were encountered. In a large number of cases the quantity was based on the water consumed with an allowance for water used for domestic purposes and for water in the product manufactured.

The sludge digestion tanks have been operated in two stages, the raw sludge being pumped first to the eight tanks equipped with gas holders. After a period of about 17 days it is transferred to the four fixed cover tanks. All tanks are heated. Digested sludge and supernatant liquor are pumped separately to Perry Oaks where ten uncovered secondary tanks are provided. Sludge is dried on open-air drying beds. Earth lagoons are provided for storage of digested sludge in winter months. The supernatant liquor is cooled, settled, and mixed with other supernatant water and drainage water and returned by sewer to Mogden for treatment.

Regarding sludge disposal costs, it was more economical to locate the sludge disposal facilities at Perry Oaks because of the much lower cost of land compared to the Mogden site. Allowing full cost of the digestion facilities and of the pumping facilities and the special features provided to protect the purity of the subsoil water, the cost of disposal is much lower than more recent methods involving artificial heat treatment. It is of interest to note that the site at Perry Oaks, 175 acres, is surrounded by a clay puddle wall, 2 ft. 3 in. thick, extending from the surface down to the underlying London clay. The maximum depth is about 25 feet. This wall was provided to protect the subsoil water.

T. L. HERRICK

Chlorinated Copperas Treatment of Sewage at Kingston-on-Thames. By EDWARD H. ELLIS. *The Surveyor,* 106, 195–196 (April 11, 1947).

The plant originally consisted of 8 sedimentation tanks, each of 120,000 gal. capacity, and served a population of 44,000. The plant treated a mixture of domestic sewage and industrial wastes. Chemical precipitation using aluminum sulfate as the coagulant was employed. Later trickling filters and humus tanks were added.

Aluminum sulfate was manufactured at the works from French bauxite but during the war this supply source was lost and a substitute precipitant had to be found. This was found in the "red mud" of the aluminum industry. This contained a little aluminum, but was principally iron oxide and sand. From this material ferrous sulfate was manufactured at the plant.

It was decided to abandon the trickling filters and humus tanks to provide space for a power plant and to increase the efficiency of chemical precipitation by the use of ferric chloride and ferric sulfate manufactured at the plant from ferrous sulfate and chlorine (product: chlorinated copperas). Copperas is readily available as a waste product of several industries. The minimum quantity of chlorinated copperas required to give a heavy floc and to effect a satisfactory reduction in suspended solids was found by experiment to be about 1,200 lb. of copperas and 160 lb. of chlorine applied, as chlorinated copperas, to 2,500,000 gal. of sewage (daily flow). The use of chlorinated copperas was found to be favorable from a cost and purification efficiency standpoint over other coagulants. The chlorinated copperas treatment gave an average reduction in suspended solids and B.O.D. of 94.8 per cent and 87.6 per cent respectively.

PAUL D. HANEY

Screening and Grit Removal in Sewage Disposal. By J. Moore. *The Surveyor,* 106, 271–272 (May 23, 1947).

The principal function of coarse screens is usually regarded as the protection of mechanical equipment following them. Present day practice seems to favor rather wide bar spacing but where pumps follow the screens it would be dangerous to provide a spacing much more than 1 in. unless special pumps are used. Where really fine spacing is required bar screens are unsuitable and perforated drums or discs should be used.

The only alternative to using pumps which will not be damaged by debris or screens is the use of Comminutors. Disintegrators (shredders) provide a method of screenings disposal but they invariably depend on screens to collect the material they handle. The principle of the Comminutor is excellent for the effects of screening and disintegration are combined in a single operation without the necessity of handling the screenings.

The permissible velocity between the bars of a screen has been regarded as 1.5 ft. per sec. but many manufacturers prefer a value of about 3.0 ft. per sec. The best position for screens and Comminutors from the maintenance standpoint would be following grit removal. However, other considerations enter into the problem of location. For example, the possibility of excessive deposition of organic solids in the grit chamber unless the screens are kept clean should be borne in mind.

The control of raking is generally automatic and a float-controlled switch can be used to turn the rakes on and off thus insuring raking of the screens only when needed.

Paul D. Haney

Sewage Disposal at Wakefield. *The Surveyor,* 106, 297–298 (June 6, 1947).

This article presents a description of the Calder Vale works of the city of Wakefield. The original works were installed in 1900 and consisted of screening, detritus settlement, coagulation with aluminum-iron compounds, sedimentation, and filtration through 34 acres of underdrained land. Since 1900 many additions have been added including trickling filters, humus tanks, lime mixing plant, laboratory, bioaeration units, and chlorination facilities. In addition, many of the structures have been modified.

The daily dry-weather flow at this plant is 2,700,000 gal., with an average daily flow of 4,700,000 gal. from a population of 54,000. The collection system is combined. Annual rainfall at Wakefield is 24 inches. Industrial wastes form about 50 per cent of the sewage and are derived principally from the manufacture of ammoniacal products; the washing and dyeing of raw wool and yarn; milk products; wire manufacturing; the processing of malt; brewery wastes; and laundries.

The plant yields a better effluent and is easiest to operate when a steady flow of 150,000 gal. per hour is maintained. This is accomplished by balancing the actual flow in the sedimentation tanks and by recirculating effluent.

Detailed descriptions of the various plant units are given.

The whole area occupied by the bioaeration plant was subject to mining subsidence of as much as 5 feet. The subsidence was not uniform. However, the structures withstood this severe test without damage.

Paul D. Haney

Chemical Treatment of Sewage. *The Surveyor,* 106, 209–210 (April 18, 1947).

This article presents a summary of a discussion on chemical treatment with particular references to the use of various iron salts. The opinion is expressed that iron compounds in the sludge may have an adverse effect on its value as a fertilizer.

Paul D. Haney

A New Chart for Highway Sewer Design. By W. Eastwood. *The Surveyor,* 106, 183–185 (April 4, 1947).

This article includes a discussion of the factors which make it difficult to design storm sewers accurately and presents a design chart which permits the design, without calculations, of sewers draining trunk roads.

The author believes that the three main factors preventing accurate sewer design are (1) lack of an accurate method of allowing for the storage capacity of a sewer, (2) many unknown errors in applying pipe-flow formulae (example: variation of Manning's "n" with the condition of pipe interior), and (3) refusal of many engineers to calculate runoff using the Ministry of Health rainfall formulae. (Abstracter's note: These formulae are similar to the Talbot formula widely used in the U. S.)

In a previous paper the author showed that the inlet time for water draining off roads to gulleys could vary between 3.5 and 8 min. and that for most roads it will be about 5 minutes. Using a 5-min. inlet time and the Ministry of Health formulae the author derives equations and constructs a chart which can be used for the direct design of sewers serving roads and, with modification, airport runways.

PAUL D. HANEY

Construction of East Hull Outfall Sewer. BY G. E. MARSHALL. *The Surveyor,* 106, 281–282 (May 30, 1947).

This article presents a description of construction work and difficulties on 1950 ft. of 9 ft. 6 in. outfall sewer. The sewer was constructed of 9-in. brickwork surrounded by concrete and was supported on piles. Brief descriptions of the following operations are given: driving steel sheet piling, excavation and timbering, driving bearing piles, sealing-coat application, invert construction, brick lining, concrete arch construction, withdrawing timbers and steel piles, and backfilling.

PAUL D. HANEY

Pollution of Rivers. *The Surveyor,* 106, 274 (May 23, 1947).

This article is a brief summary of the publication, *Report of the Water Pollution Research Board of the Department of Scientific and Industrial Research for the Period 1939 to 1945.* (H. M. Stationery Office, 1s. 3d.)

Alternating double filtration and effluent recirculation are discussed in the original report. A large experimental plant is in operation at Birmingham.

The original report gives many examples of industrial waste research. In some industries industrial waste treatment was undertaken not only to reduce pollution but to recover materials which could be reused.

One of the larger investigations was started in order to determine the effect of chlorination of sewage effluents from Coventry. It was found that effluent chlorination rendered these effluents highly poisonous to fish. It was proved that this toxicity was due to the interaction of chlorine with constituents of gas liquors which are discharged to the sewers.

Although the discharge of sewage plant effluents leads to a large immediate increase in the concentration of bacteria, their number decreases rapidly below the point of discharge. At any point the number of bacteria per unit volume of water appears to be affected to a far greater extent by a small amount of pollution a short distance upstream than by a larger amount entering at a greater distance.

PAUL D. HANEY

Influence of Aeration on Metabolic Activities of Bacteria. BY L. A. ALLEN AND G. E. EDEN. *Proc. Soc. Applied Bacteriology (Abstracts),* 1, 5 (1945).

The purpose of the experiments was to determine the effect of aeration on chemical changes produced by bacterial growth in an infusion of flax. Organic carbon, CO_2 evolved, as well as CO_2 left in the liquid, were determined with the purpose of making a carbon balance. B.O.D., volatile acids, and pH were also determined.

Flax infusion was inoculated with pure cultures of various organisms. With natural flora of flax in unsterilized infusion, organic carbon disappeared more rapidly and more CO_2 was produced in aerated series than under quiescent conditions. The pH value and volatile acids were both higher in the aerated culture than in the quiescent culture. Similar relationships existed between aerated and nonaerated samples in flax infusions inoculated with *B. coli, B. aerogenes,* and *B. subtilis,* with the exception that volatile acids were

higher in the nonaerated liquors with the pure cultures.

The loss of carbon was accounted for by the carbon dioxide produced. Aeration for 100 to 114 hours gave 30 to 31 per cent reduction of organic carbon. The B.O.D. of aerated culture was lower than the quiescent liquor inoculated with the same organism.

Anaerobic growth of bacteria in flax water tends to yield acidic and evil smelling liquor which is difficult to treat. Aeration, on the other hand, reduces the polluting strength, eliminates the foul odor, and gives a neutral or slightly alkaline liquid which might be used again in the process.

H. HEUKELEKIAN

Effect of Continuous Aeration on Bacterial Oxidation of Organic Matter. By L. A. ALLEN AND G. E. EDEN. *Jour. of Hygiene,* 44, 6, 508–517 (1946).

This investigation is connected with the problem of reducing the polluting strength of wastes produced from retting of flax. When flax is retted under stagnant conditions the liquor becomes acidic and foul, but when it is aerated it is alkaline, nonoffensive, and its polluting strength is lower. Aeration induced more complete oxidation of the substrate when the infusion was inoculated with coliform bacteria and kept under quiescent conditions. It resulted in the formation of organic acids, but with continuous aeration the organic acids were oxidized to CO_2. It is necessary to supply a sufficient amount of air in relation to the strength of the liquor to be treated, to keep the liquor aerobic and to prevent the accumulation of intermediate products.

In addition to coliform organisms the flax liquor was treated with *Bact. aerogenes* and *B. subtilis, Streptococcus achromobacterium,* and the natural flora of the flax. The magnitude of the effects depended on the nature of the organism, on the strength of the liquor, on whether or not the liquor was aerated, and on the rate of aeration. Reductions of B.O.D. varying from 26 to 92 per cent were obtained in 3 to 5 days by some of the cultures with moderate rates of aeration. The organic carbon content was reduced by 30 to 31 per cent.

With *Streptococci* and *Achromobacterium* the effects observed were very small. Aeration at higher rates with diffused air reduced the organic carbon by 50 per cent in 80 hours. The B.O.D. reductions under quiescent conditions were either negative or considerably lower than with aerated cultures.

H. HEUKELEKIAN

Re-Use of Waste Waters from Industrial Processes. By B. A. SOUTHGATE. *The Institution of Chemical Engineers.** (May 6, 1947), 8 pp.

This paper briefly discusses the industrial pollution problem, the recovery of usable materials from wastes such as metallic copper and free acid from pickling liquor, and the difficulties in treating organic industrial wastes which make it desirable to partially treat these wastes and reuse the effluent. Reuse of wastes from two industries is discussed in detail.

Anaerobic retting of flax in tanks of warm water produces a foul smelling waste with a pH usually between 4.5 and 5.5 and an average 5-day B.O.D. of about 1,800 p.p.m. Chemical treatment was unsatisfactory; even large amounts of coagulants gave not more than 50 per cent reduction in pollution character. Although studies showed that percolating filters produced an effluent suitable for reuse, this type of treatment was discarded because of the necessity for maturing the filter before the start of each season.

Studies on aeration showed that best results could be obtained by aerating the liquor during retting. In reusing retting liquor the concentration of solids and oxidizable matter increased until about the twentieth batch when it leveled off. At this point the amount of soluble and insoluble matter removed from the flax was balanced by that oxidized by aeration plus that removed with the liquor adhering to the flax. B.O.D. of the ret liquor after the first few rets fluctuated between 4,000 and 4,500 p.p.m.

The paper describes the installation used for aerated retting and the method of

* A preprint.

adding make-up water. At the end of the season the waste is disposed of by spraying over land. There is no discharge of waste waters during the retting season.

The quality of fiber is not inferior and plant construction cost, per ton of flax capacity, is nearly the same for aerated as for anerobic retting.

Treatment of beet sugar wastes is complicated by seasonal plant operation, large volumes of water used, and the fact that in Britain most plants are located in rural areas where there is little stream dilution.

Estimates of average volumes and concentrations of wastes based on data for British plants (without recirculation) are as follows:

Waste Water	Volume, Gallons (Imp.) per Ton of Beet	5-Day B.O.D., p.p.m.	Population Equivalent per Ton of Beet
Transport water	3,000	200	50
Process water	400	1,250	42
Lime-sludge drainage	60	1,750	9
Condenser water	3,000	40	10
Total (per ton of beet)	6,460	—	111

Transport water, that used to carry and wash the beets, is settled in tanks or lagoons, or both, sometimes with the aid of chemicals, and the overflow reused. At one plant, treatment with lime (300 p.p.m. CaO) and settling for 2¼ hours in a tank followed by 7 hours in a pond, resulted in reduction of B.O.D. from 1,350 to 780 p.p.m.

Process water, that drained and squeezed from the beet after the sugar is extracted, can be partially treated and reused in the diffusion battery. The waste is screened through rotary wedge-wire screens with openings 0.5 mm. by 6 mm., and is settled in a small tank. Where the process is efficient the supernatant can be mixed with fresh water and reused throughout the season without discharging any to waste. The concentration of process water returned to the diffusion system at one plant reached 8,870 p.p.m. B.O.D., and 9,260 p.p.m. suspended solids.

Reuse of process water did not adversely affect the process of extraction or the purity and quantity of the sugar produced. However, one of the difficulties in reusing process water is that there is an increase in corrosion in the diffusion system.

Where beet sugar wastes are reused there remains a large volume of concentrated waste to dispose of at the end of the season. This is discharged to lagoons and trials are being made in treating lagooned waste on trickling filters. By regulating the discharge from the lagoons and mixing the influent to the filter with river water when needed, the filters can be operated throughout the year. Results indicate that B.O.D. of the settled filter effluent can be held below 15 p.p.m.

W. A. HASFURTHER

Some Problems in the Bacteriology of Rivers. BY C. L. HANNAY. *Proc. Soc. Applied Bacteriology* (Abstracts), 1945.

Bacterial flora of the river Avon and tributaries was studied to find the extent the flora is affected by discharge of sewage and the distance this effect persists. Plate counts on nutrient agar at 20° C. and at 37° C., and presumptive counts of coliform bacteria at 37° C. and 44° C. and of fecal streptococci were determined daily over a period of several weeks from various sampling points.

Below a sewer outfall the bacterial numbers increased, and with increasing distance below the outfall they decreased rapidly. The effect was most marked with coliform bacteria on McConkey broth at 44° C. and with fecal streptococci. Below the outfall, fecal streptococci decreased by 97 per cent in less than 3 miles, and below the other outfall by 97.4 per cent in 1.9 miles. With methods of counting which included bacteria washed in from the river banks, the decreases were of a lower order. The full effect of the marked increase in counts after a heavy rainfall was evident at some sampling points on the actual day of rain, and at other points it was evident the next day. The time taken appeared to depend on the position of sampling point relative to storm water discharge and secondary sources of pollution on the banks.

H. HEUKELEKIAN

The Sterilization of Sewage Effluents by Means of Gaseous Chlorine. By J. A. McLachlan and J. R. Gaillard. Annual Report of the City Engineer of Johannesburg, 1946, pp. 33–47.

Object of the work was to produce complete sterility of well-oxidized sewage effluent using presumptive test for *B. coli* and total agar count. Complete bacterial sterility was aimed at with the hope that it might result in the inactivation of the poliomyelitis virus. Variables studied were (1) chlorine dosage, 0.2 to 120 p.p.m.; (2) contact time, 10 min. to 24 hr.; and (3) chlorine demand. *B. coli* was tested in 10 ml. portions and plate counts 1 ml. portions. Substrate used was sand filter effluent.

With a 10 min. contact period chlorine doses of 15 to 95 p.p.m. were necessary to destroy *B. coli* and all colony-producing organisms on agar. It requires great deal more chlorine to destroy all growths on agar plates with 1 ml. inoculations than to get a negative *B. coli* test in 10 ml. sample. The latter can be accomplished with dosages as low as 5.2 p.p.m. of chlorine and 10 min. contact time.

It was concluded that the sterility as indicated by negative presumptive test in 10 ml. and a negligible plate count on agar with 1 ml. sample may be taken as an index of the efficiency of chlorination. The choice is between high dosages (100 p.p.m.) with short contact period (10 min.) and lower dosages with longer contact period (24 hours).

The disadvantage of the first is the adverse effect of high residuals in the effluent on the soil or in the river, depending on the final method of disposal. The second alternative entails the cost of large contact tanks. The chlorine demand concept as applied to the disinfection of sewage effluent is criticized. No indication of breakpoint has been observed with dosages up to 120 p.p.m.

H. Heukelekian

Proposal for a More Rigid Standardization of the "Oxygen Absorbed from Permanganate" Test. By P. B. B. Vosloo. *Public Health* (South Africa), **11**, 11 (July, 1947).

Since the reaction in the oxygen consumed test is not an instantaneous one, it must be governed by the Law of Mass Action and the amount of oxygen absorbed in a fixed time depends upon the concentration of the permanganate, the sulfuric acid, and the organic matter in the mixed solution. It is particularly necessary that the concentration of permanganate be kept as nearly the same as possible in each test. The maximum value for the oxygen absorbed is obtained when about one-half of the permanganate remains at the end of the test. If the sample is too small and the concentration of organic matter too low or if the sample is large and the concentration of permanganate drops to a low value early in the test, the oxygen absorbed value is low. Therefore, if the oxygen absorbed test is to be used to compare the oxidizable organic matter in different types of samples, the concentration of organic matter in the various samples should be approximately the same at the time of testing. Since it is impracticable to concentrate the organic matter in an effluent, it is necessary to dilute a sewage and use the dilution factor in the calculation of the result.

Gail P. Edwards

Funds for Potable Water and Sewerage in Chile. By Eduardo Aguirre S. *Organo Oficial de la Asociacion Interamericana de Ingenieria Sanitaria*, **1**, (July, 1947).

Because the individual cities of Chile lack the means for the construction and operation of public water supplies and sewerage systems, the national government has assumed charge of all this work. By Law No. 1835 of Feb. 12, 1906, the government was authorized to spend approximately $6,500,000 during 5 years in the execution of numerous works. These works were to be carried out by the Inspection General of Potable Water and Sanitation with approval of the president of Chile. The systems constructed were to be considered government property until the amounts invested were repaid by the individual municipalities. The government also fixed the water rates to be charged and required the use of water meters.

After the law was passed the Department of Hydraulics was created, under the Ministry of Public Works, for the study and construction of all works. The administration of the works was put under the Inspection General of Potable Water and Drainage, now called the General Direction of Potable Water and Sewerage, under the Ministry of the Interior. The results have been good as the technicians of both departments cooperate. The Direction General now has 35 engineers and the Department of Hydraulics 78 engineers and 2 architects, with numerous other personnel, including laboratory technicians, in both offices. Due to the existence of this large force it has been possible to design and construct for many small cities numerous works in accordance with modern developments elsewhere.

To raise funds, Laws 3849 and 3990, of 1922, were passed to permit the change in taxation from 3 to 4 per thousand. These laws established the basis for carrying out the work of sewerage in cities of less than 10,000 population, namely: (1) When 70 per cent of the property owners petition a city government, it in turn can request the national government to construct the works. The city must also provide 30 per cent of the value of the preliminary work. The national government provides the balance. (2) The annual revenue from the sewer rates must be sufficient to cover the cost of administration of the system, interest on the capital invested, and not less than one-half of the amortization charges of the capital investment. (3) The maximum tax rate on properties having sewers installed under this system is 6 per thousand.

Due to improvements in the water and sewerage systems the capital invested has increased annually and has required more funds from the national government which has delayed the time when these systems revert back to their respective municipalities. In general, the income from these completed works takes care of the costs of administration, and the interest and amortization of the construction loans.

As funds from the national budget do not always meet the requirements for this service, a new law was approved on July 15, 1941, permitting the government to install water systems in towns with populations of less than 1,000. Later, in 1945, Law No. 8080 was passed approving a six-year plan for spending approximately $1,680,000 in equal amounts for water and sewage works. The 1941 law provides for an amount of about $600,000, annually, to be set aside in the national budget and if the net income from all water and sewage works throughout the country is higher than this, the excess is to be used for additional construction of the same type. Also, additional income was provided by a special real estate tax of 1 per 1,000 in cities already possessing water systems. These funds grow with the development of the country, and to date the annual revenue from the net income is approximately $1,560,000, and from the special tax $760,000. With these special funds and some additional special funds, Chile now has the annual sum of $3,280,000 for the construction of water and sewage works.

Four factors are set up in the law of 1941 for arranging the order of preference for works to be done. These are: the number of inhabitants, the death rate, the value of the urban property, and the cost of the desired works. In cases where there is need of expansion or improvement of existing works, the preceeding factors are taken into consideration as well as the degree of the necessity. This is decided by the General Direction of Potable Water and Sewerage, or by the Potable Water Company of Santiago, in the case of the city of Santiago.

Present plans propose the construction of water works for 77 cities of more than 1,000 population now without water supply and the improvement and enlargement of the works of 85 cities. The total estimated cost of this work, over a period of 15 years, is $40,000,000. New works now under way in Santiago for potable water will cost $16,000,000, and those of Valparaiso and Vina del Mar, also under way, are estimated at $11,600,000. Thus, in Chile, with a total population of 5,300,000, the annual amount estimated for construction of water supply and sewerage works is $0.61 per inhabitant.

The sewerage system situation is comparable, although there is a small present deficit in the income from these installa-

tions. The present annual income is $840,000, which will increase periodically. Construction of sewerage systems for more than 17 towns is planned for the next 15 years and the existing systems in 28 cities will be enlarged and improved during the same period. This work is estimated to cost $16,400,000. Of this there will be spent in Santiago alone $7,600,000 for the general sewerage system and $6,000,000 for the sewage treatment plant. The total sum mentioned represents an annual per capita quota of about $0.21.

To assist in this general plan the United States government agreed in 1943 to provide financial aid to Latin American republics for this type of work. To promote this in Chile, the Institute of Inter-American Affairs created the Interamerican Cooperative Department of Health Works as a branch of the General Direction of Sanitation. This agency was charged with the expenditures of $5,000,000 in a period of 5 years in the construction, expansion, and improvement of water and sewerage works. To this the Chilean government added about $2,000,000. These amounts are not included in the sums mentioned previously. Up to June, 1946, the Interamerican Cooperative Department had invested $1,500,000 and had completed the projects of Villa Alemana; La Calera; San Jose de Maipo; San Vicente de Tagua-Tagua; and a suburb of Antofagasta. Under construction at the present time are the sewer systems of Llay-Llay; Tome, Ancud; and the northern section of the City of Santiago; also sewage treatment plants for Villa Alemana, La Calera and Llay-Llay and other smaller works in rural communities. A summary of the water supply and sewerage works of Chile, based on 1940 census figures, is as follows:

Total population of Chile	5,023,539
Urban population (52.5%)	2,637,327
Rural population (47.5%)	2,386,212
Population served by public water supplies	1,995,883
Population connected to public sewerage systems	1,310,027
Urban population served by public water systems	75%
Urban population served by public sewerage systems	49.5%
Total population served by public water supply systems	40.0%
Total population served by public sewerage systems	26.2%
Number of municipalities having public water systems	152
Number of municipalities having sewerage systems	61
City of Santiago	
Population	997,118
Population served by public water system	950,000
Total area provided with public water supplies (acres)	49,200
Metered consumption in year 1944 (m.g.d.)	45.35
Population connected to sewerage system	480,002
Area sewered (acres)	11,010

E. B. BESSELIEVRE

Sanitary Engineering Activities in Uruguay. BY JUAN JOSE SBARBARO, JUAN C. ALTOBERRO, ADAM GIANONI, AND LUIS GIANNATASIO. *Organ Oficial de la Asociacion Interamericana de Ingenieria Sanitaria,* **1**, 8–41 (July, 1947).

The first sanitary works of Uruguay was a system of drainage for the city of Montevideo, constructed in 1852. Population then was 60,000. The system was put into operation in 1856. Due to use of rain water for water supply, mortality was 27 per 1,000. Water supply system was put into operation in 1871 with river as source. Up to 1907 Montevideo was the only city in Uruguay with drainage and public water supply. In 1907 the Department of Sanitation was formed under the Ministry of Public Works. In 1910 sanitary works were approved for the 19 departmental or provincial capitals of the country, and in 1911 a resolution was put before the parliament for such works in all cities over 5,000 population, but this did not pass. In 1915 the Ulen Contracting Co. of the United States started work on water supply and sewerage for the cities of Salto, Paysandu, and Mercedes. In 1916 the city of Montevideo took over all private works and formed the Sanitary Works Section of the city government.

Recently the national government appointed a special commission to study the improvement of water supply and sanita-

tion for the entire country. Up to the present time approximately $40,000,000 has been spent in Uruguay for water supply, sewers, and sewage treatment, of which approximately $11,000,000 was spent by the Montevideo Waterworks Co., Ltd., a private British company which owns the water works and distribution system for the capital city.

At present there are 22 sewerage systems functioning, including that of the city of Montevideo. Practically all sewage outside of Montevideo is of domestic origin. Systems are generally separate. Sewage flow is estimated at 90 per cent of water consumption which is normally 40 gal. per capita per day, with an allowance for infiltration. Minimum size of pipe or conduits for drainage is 8 in. and minimum velocity is 2.5 ft. per sec., for separate systems.

For economic reasons sewage treatment to the present has been strictly limited to supply the immediate necessities, but provision has been made in plans for amplification of the treatment when circumstances require it. The plans propose hand-raked bar screens with screenings incineration, and Imhoff tanks with trickling filters for secondary treatment. Secondary treatment is not considered necessary except in certain cases outside of the capital area. In all isolated places disinfection by sodium hypochlorite is employed.

Primary treatment by Imhoff tanks is considered adequate for the climatic conditions and preferable to other systems which employ mechanisms because of the limited knowledge and capacity of the operators. It is considered that mechanization in countries where the mechanisms are not made would be the source of trouble in cases of breakdown. Also the mechanical type of plant is more expensive initially. For similar reasons, bacterial filters have been used for cities in the interior because of the higher cost of other treatment methods, such as activated sludge. The location of the city of Montevideo on the shore of the enormous Rio de la Plata indicates the discharge of the sewage into that stream, but due to the enormous increase in population, the numerous discharge lines, and the recreational development of the shore for bathing beaches, city authorities have been obliged to consider treatment of sewage as an urgent and major problem.

All estates which are on drainage lines are obliged by law to connect to the public services on penalty of being declared uninhabitable for noncompliance. The charge for these connections is based on the price per linear meter (3.28 ft.) of the pipe, the character of the ground, and the type of pavement.

Statistics for the 84 sewerage and water systems reported in the entire country are as follows:

Total population of Uruguay	2,270,000
Total population of cities with treated water	1,615,000
Total population of cities with sewage treatment plants	1,208,100
Total population served by the 84 cities in the report	667,350
Number of cities with potable water supply	84
Number of cities with sewerage systems	19
Total number of sewer connections	17,644
Length of sewer systems in 84 cities reporting (miles)	313
Total number of flush tanks in 84 cities reporting	1,387

The sewer systems for sewage alone are usually of concrete pipes, each 3.2 ft. long. Concrete pipes have been in use for 26 years with no objectionable results. They are locally made. Joints are made with cement mortar and fine sand in equal proportions. For large sewers, oval sections of the normal English type are constructed in place of concrete. At the upper ends of all sewer lines flush tanks with a capacity of approximately 160 gal., minimum, are provided.

The bar screens at treatment plants are set at an angle of 25° to 30° from the horizontal, with free openings of about 1 inch. They are cleaned by hand, and screenings are burned in incinerators. Imhoff tanks are of rectangular type or circular, with horizontal flow. In circular tanks the ventilation stack occupies the central zone. The period of detention is usually about 2 hours. Due to the temperate climate the design units are lower than those used in the United States. While it is common to use a unit of 0.88 cu. ft. per capita per day for the volume of Imhoff tanks, units with volumes of

only 0.6 cu. ft. per capita have operated successfully. In some localities lime is used to correct the pH of the sludge. Sludge drying beds are uncovered. Areas provided are based on 0.33 sq. ft. per capita. Trickling filters are of conventional type provided with fixed nozzles, because these are claimed to provide better distribution and cost less than rotating distributors. Sizes are based on 9 to 11 persons per cubic meter of filter medium. Final settling tanks are of Dortmund type, with detention periods of from 1 to 2 hours. The Central Laboratory makes limited analyses on sewage and moisture content of sludge.

The article is accompanied by one table of statistics on 84 cities of Uruguay.

E. B. BESSELIEVRE

Poliomyelites Virus in Urban Sewage in Epidemic and in Non-epidemic Times. By JOSEPH L. MELNICK. *The American Journal of Hygiene,* 45, 2, 240–253 (1947).

The investigation was undertaken to determine whether or not virulent poliomyelites virus exists in urban sewage at all times, winter and summer. If this is the case, pathogenesis of human poliomyelites is likely to be due to lowering of human resistance at certain times. Tests were run on (a) Chicago sewage in 1943 during and after the peak of poliomyelites epidemic; and (b) New York sewage over a period of 6 years (1940–1945), at monthly intervals. The tests were run with improved methods having greater sensitivity on monkeys.

Of 61 tests made in Chicago during the peak of the epidemic, 6 were positive. Tests of samples collected after the epidemic had subsided were all negative. The Imhoff tank influent samples to the West Side plant were all negative while two effluent samples from the tanks were positive, in spite of the fact that effluent samples were taken after proper detention period. Imhoff tank sludge did not give a positive result. All sewage samples from hospitals treating poliomyelites patients were negative.

New York city samples were taken at the Manhattan grit chamber. In 2 out of 6 years no positive tests were obtained although in one of these years there were a considerable number of polio cases on the sewer line sampled. All the positive tests were obtained in late summer and fall when the number of cases was at a maximum. Calculations show that in Chicago 6,000,000 monkey-infectious doses of virus were leaving the sewage disposal plant per minute, and in New York the same value was 500,000 doses. It is suggested that on this basis approximately 6 per cent of the people in Manhattan in New York City may have been carriers of poliomyelites virus.

H. HEUKELEKIAN

The Role of Water in the Etiology of Poliomyelites. By RALPH R. SCOBEY, M.D. *Archives of Pediatrics, New York,* 63, 567–580 (November, 1946).

The author points to the evidence of severe epidemics of poliomyelites during years of severe droughts and to the periodicity of 15 years for both phenomena. Severe droughts and epidemics both occurred in 1930 and 1946. The prevalence of the disease also occurs during the dry season of the year.

Cyanide may be produced as a result of decomposition of cyanophore glucosides from vegetable matter. Sulfocyanate may be present in animal excretions which can be converted to cyanide by oxidizing agents. Cyanides may also be produced as a result of putrefaction of animal tissue. Cyanides produced from these sources may be washed from the soil into the ground or surface waters and may be augmented by the cyanides produced from the same sources in surface waters. Hydrocyanic acid may be present in the water in sufficient quantities to produce poliomyelites and other illnesses such as gastrointestinal disturbances and ricketts. High incidence of poliomyelites may occur during droughts in certain parts of the country and with excessive precipitation in other districts. Cyanide poisoning can cause gastrointestinal disturbances and neurological symptoms identical with those of poliomyelites. Under conditions of drought, and consequent high cyanide content of water, gastrointestinal disturbances

and epidemic poliomyelites would not be separate entities but conditions arising from the same source.

Foods harvested in advance of their natural maturity contain a greater quantity of glucosides capable of producing hydrocyanic acid than those permitted to reach a natural maturity. Drought would also increase the hydrocyanic acid-producing glucosides in foods. Patients treated with sulfocyanates show toxic effects.

H. HEUKELEKIAN

Analogous Reaction of the Poliomyelites Virus and Cyanogen Compounds. BY RALPH R. SCOBEY, M.D. *Archives of Pediatrics, New York,* **64**, 132–143 (March, 1947).

Hydrocyanic acid is capable of producing symptoms and pathological lesions identical to those of poliomyelites. The virus may be an endogenous virus protein produced in the body by cyanides and therefore the virus is an excretion product which leaves the body instead of entering it. The virus may be a cyanolytic enzyme capable of producing or accelerating the production of hydrocanic acid. Both cyanides and poliomyelites virus are destroyed by heat and oxidizing agents. In both poliomyelites and cyanide poisoning there is a functional disturbance of the thyroid gland and hypothyroid individuals show a susceptibility to poliomyelites. Other analogies are made between susceptibility to poliomyelites and cyanides such as undernourishment, stage and rate of growth of an animal, effect of light, humidity, and temperature.

H. HEUKELEKIAN

Paralytic Shellfish Disease and Poliomyelites. BY RALPH R. SCOBEY, M.D. *Archives of Pediatrics, New York,* **64**, 350–363 (July, 1947).

There are many mysteries and anomolies regarding poliomyelites which have not been adequately explained on the basis of virus infection. The author does not deny that a virus obtained from excreta or sewage will produce a disease in animals, which the author calls pseudopoliomyelites, but no proof can be found that a human being develops the disease as a result of infection by the same virus. When one disregards the virus theory of poliomyelites, then a clearer understanding results, and according to the author the observed facts regarding the disease fit in better on the basis of the non-virus character of the causative agent.

Paralytic shellfish (mussel poisoning) disease is an acute poisoning with profound action on the nervous system. The first extensive epidemic of this disease in the United States occurred in California in 1927. In the same year occurred the greatest number of poliomyelites cases in that state. The paralytic shellfish disease has been observed with greatest frequency in the proximity of mouths of rivers entering the Pacific Ocean. It occurs in the summer months, similar to poliomyelites. The symptoms of paralytic shellfish disease are three types: (1) gastrointestinal type, (2) nervous or allergic type, and (3) paralytic type, which is the fatal form. Cooked mussels were just as potent as the raw ones. This disease shows a striking similarity to the symptoms of poliomyelites. The poisonous property is not inherent in mussels but originates from the food eaten by them. Poisonous mussels have in their stomach contents certain plankton organisms which are either not found or are present in very small amounts in the stomachs of nontoxic mussels. The poison in the plankton was identical with the poison in the muscles.

Fresh-water plankton, especially blue-green algae, are definitely linked to several intoxications in animals. Thus algae in addition to imparting tastes to the water may be important in the production of acute gastro-enteritis.

The author compares the distribution of the 1927 California (San Francisco area) cases of poliomyelites and paralytic shellfish disease and finds a close relationship. It was observed that shellfish in the Pacific Ocean were accidentally poisoned by poisonous plankton that were in turn poisoned by substances originating in the watershed areas involved. The existence of extensive epidemics of poliomyelites and of paralytic shellfish disease at the same time was probably not a coincidence but rather the same etiological factor—

hydrocyanic acid—was responsible for each of these diseases.

Hydrocyanic acid can be absorbed through the skin and therefore bathers and waders in polluted water can absorb enough cyanide to produce this disease. The nervous or allergic type of paralytic shellfish disease has no resemblance to the symptoms of poliomyelites. But poliomyelites is not one disease but rather a group of diseases produced by a common etiological factor—hydrocyanic acid. Many fruits containing cyanophore glucosides produce allergic manifestations.

H. HEUKELEKIAN

Species of Sulfur Bacteria Associated With the Corrosion of Concrete. BY C. D. PARKER. *Nature,* 159, 439 (March 29, 1947).

The author had shown previously that the corrosion of concrete is due to the production of sulfuric acid from sulfur by *Thiobacillus concretivorus.* But this organism cannot exist at pH values higher than 6.5 (the pH value of fresh uncorroded concrete being 11–12). Furthermore, this organism cannot utilize hydrogen sulfide which is the primary source of sulfur and corrosion in sewers. The mechanism of change of hydrogen sulfide to sulfur was also a moot question.

The author has been able to fill some of the gaps of the chain of reactions in the corrosion of concrete by the isolation of other groups of bacteria during the early stages of corrosion. The first group resembles *Thiobacillus thioparus* which oxidizes thiosulfate to sulfate and polythionate and elemental sulfur and hydrogen sulfide to sulfur, reducing the pH to 3.0–3.3. They exist over a pH range of 3.5 to 8.5. The second group consists of miscellaneous species which are characterized by their ability to oxidize thiosulfates to polythionates and sulfate without the formation of elemental sulfur. They tolerate a wide range of pH (2.0–10.5) but the optimum is between 7 and 10. They exist in hydrogen sulfide atmosphere with calcium carbonate but will not grow with elemental sulfur or sulfides as the source of sulfur.

The three groups of bacteria predominate at different stages of corrosion, the miscellaneous group in initial stage (pH 11–9), the *Thioparus* species between pH 9 and 5 and the *Th. concretivorus* alone is present during the final stage of free-acid formation below pH 5.0. The chain of events is explained as follows: on fresh concrete with a pH of 11–12 and exposed to hydrogen sulfide in the sewer atmosphere, chemical changes take place involving carbonation which lowers the pH to 8.4. Fixation of hydrogen sulfide as the thiosulfuric and polythionic acids also occurs which further lowers the pH to 7.5. Simultaneously with these chemical changes the miscellaneous group of bacteria develop, oxidizing the thiosulfates. *Thioparus* group becomes active below pH 9.0 converting the thiosulfates and polythionates to sulfur and sulfuric acid which further drops the pH value. As the pH drops below 5, the *Th. concretivorus* becomes active. Corrosion increases with the activity of the latter organism and the resultant increase in production of acid. Thus, while the primary corrosive agent is hydrogen sulfide none of the bacteria can utilize sulfides. It is through the intermediate production of the sulfates, polythionates and sulfur by chemical means that the corrosion proceeds.

H. HEUKELEKIAN

The Role of Microorganisms in Acid Mine Drainage. BY ARTHUR R. COLMER AND M. E. HINKLE. *Science,* 106, 2751, 253–256 (1947).

Atmospheric oxidation of acid mine water converts the iron bisulfide to ferrous sulfate and sulfuric acid. The former in acid solution is further oxidized to ferric sulfate which hydrolyzes to ferric hydroxide, producing the rusty color. The purpose of the paper is to show the role played by microorganisms in bringing about these changes. The presence of air, although essential, is not the sole factor in bringing about the conversion of ferrous sulfate to ferric sulfate because with the addition of a sufficient quantity of disinfectants and bacteriostatic agents, acid mine water did not change to amber and rusty color even when exposed to air.

By repeated transfers into Seitz-filtered

acid mine water, an enrichment culture was obtained which was plated on agar made up with sterile mine water. Amber color appeared on the agar and small colonies were apparent in and around the colored areas. By repeated plating on this agar, pure cultures of bacteria were obtained which were gram negative, nonspore forming rods and were capable of bringing about the oxidation and precipitation of the iron in sterile mine water. The organism does not grow in the synthetic sulfur medium used as a substrate for *Thiobacillus thiooxidans*. In addition to the bacterium several fungi have been isolated from the mine drainage which do not appear to cause a rapid oxidation of ferrous to ferric iron.

A second organism was isolated by enrichment of acid mine water in synthetic sulfur medium used for the growth of *Thiobacillus thiooxidans*. This organism oxidizes sulfur to sulfuric acid but will not oxidize ferrous iron. The second organism has the same morphological and physiological characteristics of *Thiobacillus thiooxidans*. The gaseous environment of the mines is suitable for the growth of this sulfur oxidizing organism. The acidity of the drainage water is no obstacle to its growth as it is known to tolerate extremly acid reactions. Sulfur essential for the growth of the organism exists in coal.

H. HEUKELEKIAN

Effects of Coal Strip Mining upon Water Supplies. By RAYMOND H. SNYDER. *J. Amer. Water Wks. Assn.*, 39, 751–756 (August, 1947).

In recent years the open pit or "strip" method of mining coal has come into much wider use and closer competition with deep-mined coal. As a result of this development came the sulfate wastes which invariably attend strip mining, and which create a critical problem for the water works industry.

In strip-mining operations the overlying burden is removed by large power shovels or draglines. The process results in the deposition of carbonaceous material on the top of the excavated material or spoil bank. Coal waste and the associated dark shales contain carbonaceous material that has a small percentage of iron disulfide in the form of the mineral pyrite. This is in itself harmless because it is insoluble. When exposed to the action of air and water, however, it readily oxidizes into the soluble iron sulfate. The hydrolysis of iron sulfate forms sulfuric acid, which neutralizes the normal alkalinity of the water and attacks the shales, clays and sandstones, releasing calcium, magnesium, aluminum and manganese, in addition to the iron from the pyrite. Typical reactions in the creation of pollution are:

$$2\,FeS_2 + 2\,H_2O + 7\,O_2 \rightarrow 2\,FeSO_4 + 2\,H_2SO_4$$

$$4\,FeSO_4 + 2\,H_2SO_4 + O_2 \rightarrow 2\,Fe_2(SO_4)_3 + 2\,H_2O$$

$$12\,FeSO_4 + 3\,O_2 + 6\,H_2O \rightarrow 4\,Fe_2(SO_4)_3 + 4\,Fe(OH)_3$$

$$H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2O + CO_2$$

$$H_2SO_4 + Ca(HCO_3)_2 \rightarrow CaSO_4 + 2\,H_2O + 2\,CO_2$$

These reactions occur quite readily in the porous spoil banks and result in the pollution of surface waters and even ground waters in some cases.

This paper is chiefly concerned with the pollution of the supply of the West Penn Water Co., in Pennsylvania, which serves 8,300 people and a number of large industries in McDonald, Burgettstown and the surrounding vicinity. Between the years of 1942 and 1945 there was considerable stripping activity on the watershed. As the maximum pollution does not take place until about 12 to 18 months afterward, the damage is usually far in advance of the conditions when they are discovered. In the case of the West Penn Water Co., the effect of earlier stripping did not become manifest until the beginning of 1944 when general observations were undertaken.

After unsuccessfully attempting to negotiate a financial settlement with the responsible coal operators, it was determined to institute legal proceedings. A hearing for preliminary injunction was held in April, 1945, at which time the court decided that it was too late for injunctive relief, inasmuch as irreparable damage already had been done. The summer of 1945 was spent in preparing data for a damage suit and the hearing for final in-

junction, which was held in September, 1945. This resulted in an out-of-court settlement for $500,000.

During the lawsuit a number of important points were brought out:

1. By 1945 the water had attained an increase in hardness from less than 100 p.p.m. to an average of 392 p.p.m. and a maximum of 490 p.p.m.; a pH of 4.3; and a free acid content of 28 p.p.m.

2. Some of the polluted water leaving the stripping operations had up to 9,000 p.p.m. of hardness; 1,560 p.p.m. of free acid; 20,696 p.p.m. of total solids; 3,333 p.p.m. of iron; 240 p.p.m. of manganese; 400 p.p.m. of color; and 9,770 p.p.m. of sulfates.

3. It was found impractical to relieve the pollution by backfilling and contouring.

4. Sieve analysis revealed that, after about 18 months of weathering, coal waste was so broken up that 54 times as much surface was exposed to the action of air and water than a solid block of coal offered before being mined.

5. A tabulation of the results of stream gaging and sampling, which was finally expressed in terms of pounds of sulfate per day from each polluter, made possible the evaluation of the amount of damage for which each operator was responsible.

6. The valuation of the company before and after pollution was presented.

On February 2, 1947, the West Penn Water Company placed a new supply in operation at a cost of $700,000.

In conclusion it is stated that the whole problem is becoming more serious due to the increasing magnitude of strip-mining operations and that the need of adequate legislation for the protection of water supplies is evident.

Discussions

By Joseph A. Beck: The West Penn Water Company suit was a victory for this water company. The Punxsutawney Water Service Company in Clearfield County, Pennsylvania, was not so fortunate, as they were unable to secure an injunction to enjoin strip mining on the watershed. Since then increased activity has made pollution quite evident. The failure of the courts to enjoin strip mining in this drainage basin will eventually result in the necessity of abandonment of the supply.

Present legislation on the statute books of the state of Pennsylvania affects the protection of watersheds from pollution and the Supreme Court of the state has ruled that public water supplies were to be protected against coal mining pollution. The Pure Streams Act, approved in 1937 and amended in 1945, gives the Sanitary Water Board broad power to protect water used for public water supply purposes from pollution. However, the present law appears to provide inadequate protection, and the writer believes that strip mining in the watershed of a public water supply should be prohibited outright by the courts.

By William J. Murdoch: This discussion elaborates on the method and results of stream gaging and sampling to determine the amount of damage to the West Penn Water Co. for which each operator was responsible. The sulfate content was used as the index for pollution, and the content of normal, unpolluted streams (30 to 50 p.p.m.) was used as a comparison.

By Carl Kear: The problem of strip-mining operations on a watershed of the Municipal Authority of the borough of Minersville, Pa., is discussed. In 1927 coal strip-mining operations caused acute conditions, but before the courts could hear the case the mine operators entered bankruptcy proceedings. Since that time the pollution has cost approximately $1,400 per year for removal.

A new threat to the supply has appeared with an application to the Sanitary Water Board for permission to engage in strip mining operations in the area. Upon the basis of testimony given, however, it appears that the primary threat to the utility will not be one of pollution but of diversion of its supply. The mine operators propose to protect the utility's supply by diverting the drainage from stripping operations by flume to a point beyond the reservoir, which is the source of supply. As early estimates indicate this will remove about 15 per cent of the daily supply taken from this stream, the resulting reduction in available water presents a serious problem.

Robert P. Lowe

Waste Treatment Guide. By The Interstate Commission on the Potomac River Basin.* 39 pp.

The guide has been prepared for the information of the municipalities and industries faced with industrial waste treatment problems. The wastes discussed have been selected from the needs of the Potomac River Basin. The important waste treatment processes are described briefly with the relation between primary and secondary treatments. Responsible state officials are listed for the states in the Potomac River Basin. These are Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia.

The guide lists the origin and types of wastes, effects on the river, volume of wastes, characteristics of wastes, remedial measures, and treatment methods. The technical terms used in the guide are defined and a detailed description of each waste treatment process given. The wastes included are those from bottling plants (soft drinks), breweries, canning plants, chemical manufacturing plants, dairy plants, distilleries, farms, gas-producing plants, laundries, metal plants, mines, municipalities, petroleum processing plants, pulp and paper mills, quarry and sand washing plants, rayon manufacturing plants, saw mills and lumber mills, slaughterhouses and meat packing plants, tanneries, and textile mills.

A reading list and previous publications of the commission are given. Thirty-nine pages, three illustrations.

RALPH FUHRMAN

* 502 Transportation Bldg., Washington 6, D. C.

Successful Disposal Methods for Synthetic Rubber Waste. By C. C. RUCHHOFT, O. R. PLACAK, AND F. E. DEMARTINI. *Civil Engineering*, 17, 2 (February, 1947).

The paper is a condensation of the results obtained in laboratory studies of rubber waste treatment. In synthetic rubber manufacture butadiene polymers and copolymers are used. Butadiene and styrene have been used mostly in the United States from alcohol and petroleum fractions. The following table indicates analyses of typical wastes from synthetics of the industry.

Plant Area Involved	Approx. Daily Discharge in Million Gal.	pH	Total Solids, p.p.m.	Suspended Solids, p.p.m.	5-day B.O.D., p.p.m.	Odor Concentration
(1) Butadiene waste	1.90	2.8	300	27.6	2,550	16,100
(2) Styrene waste	4.62	6.2	150	4.5	180	690
Copolymer plant						
(3) Process waste	2.34	4.3	5,580	12.3	69	62
(4) Recovery and reactor	0.39	8.0	570	23.6	492	8,760
(5) Main sewer *	2.63	7.0	6,530	46.0	168	930
(6) Main outfall, Institute *	119.4	5.4	270	15.5	81	460

* (5) Represents the mixture of (3) and (4). (6) Represents the mixture of (1), (2), and (5) plus large quantities of condenser water.

The odor concentration reported is the reciprocal of the dilution required to make the odor just detectable.

Initially the studies were made along conventional methods of water purification to remove taste and odors caused by these wastes. The processes investigated were: coagulation, ozonation, addition of activated carbon, break-point chlorination, and aeration by diffusion and spraying. Coagulation and ozonation were of no value. Large doses of activated carbon, such as 100 p.p.m or more, completely removed the tastes and odors.

Chlorination at the break point gave best results but for strong wastes was valueless. Aeration by diffusion produced some odor removal, with very effective results at 50° C.

Treatment of these wastes should include removal of taste and odor producing systems as well as reduction of organic content.

Activated sludge treatment gave a 90 per cent B.O.D. reduction in butadiene and styrene wastes under the following condi-

tions only:

1. that an aeration period of about 24 hours be provided,
2. that no more than 25 per cent of butadiene and/or styrene waste be fed with a good domestic sewage,
3. that the sludge solids be maintained, in the aeration mixture, preferably above 2,000 p.p.m.

The investigations showed that even with high B.O.D. removals a high degree of removal of tastes and odors did not necessarily follow.

Trickling filter treatment gave a B.O.D. reduction of 90 per cent for the sewage and waste dilution and 86 per cent for undiluted waste. Odor concentration was reduced from 750 to 16.

The treatment of water polluted with the activated sludge effluent was investigated. Fifty to sixty p.p.m. of activated carbon was needed to remove taste and odor from a dilution containing 10 per cent plant effluent and 90 per cent tap water. Aeration, settling, and coagulation were of little practical benefit in reduction of tastes and odors from the same mixture.

The next logical step will be the extension of these laboratory experiments to pilot plant experiments. No development along this line has yet occurred.

RALPH FUHRMAN

The Meat Packing Plant Waste Disposal Problem. BY E. F. ELDRIDGE. Michigan Engineering Experiment Station *Bulletin 105,* 50 pages, Michigan State College, East Lansing, Mich.

General

Differing from most types of industrial wastes, slaughterhouse wastes may carry organisms responsible for disease in man and animals and thus have public health significance. The organic compounds carried in slaughterhouse wastes are responsible for most of the pollution from this industry. The organic matter has its origin in the blood, manure, hair, dirt, and grease washed from the floor and equipment. When a small slaughterhouse has access to a city treatment plant, grease removal is generally all that is required before the plant can be connected to the city system. Packing plants which, in addition to slaughtering the animals, produce a large number of byproducts must, in most cases, provide preliminary treatment before connecting to the city system. Table I lists some of the characteristics of slaughterhouse and packing plant wastes.

TABLE I.—Content of Wastes on Basis of Kill

Type of Kill	Volume per Animal, gal.	Suspended Solids, p.p.m.	Organic Nitrogen, p.p.m.	B.O.D., p.p.m.	Population Equivalent per Animal
Slaughterhouse Wastes					
Cattle	395	820	154	996	19.6
Hogs	143	717	122	1,046	7.5
Mixed	359	929	324	2,240	40.2
Packing Plant Wastes					
Cattle	2,189	467	....	448	49.2
Hogs	552	633	....	1,030	28.6
Mixed	996	457	113	635	30.7

Selecting Treatment Method

A careful survey of the plant in question covering flow sheet and magnitude of operations, quantities and characteristics of wastes, and possible segregation of relatively clear water should be made prior to deciding upon which type of treatment to use. From the results of the survey the wastes should be divided into three groups: (1) those containing salvable materials, (2) those which can be discharged directly, and (3) those which must be treated.

Salvable materials from slaughterhouse and packing plant wastes consist of manure, fleshings, blood, and grease. Manure and fleshings can be kept out of the wastes by the use of screens and careful operations on the killing floor. Blood can be segregated by the use of a smooth surfaced collecting trough located beneath the bleeding animal. The grease can be removed by a trap located as near the source as possible. The trap should have a capacity for about a 10 min. maximum flow and should be designed for a velocity of about 4 or 5 ft. per minute.

For large plants the following processes are most commonly used: plain sedimentation or flotation with sludge removal, biological filtration, activated sludge, superchlorination, and chemical coagulation.

The Small Plant

Two treatment processes are available for use on the wastes from small slaughterhouses and packing plants. Biological filtration and superchlorination are the processes, but they both must be preceded by effective grease removal.

Primary treatment, which is all that is necessary in some small plants, can best be provided by a septic tank, following grease interception. Septic tanks are low in efficiency and produce an effluent which has an unpleasant odor, but they are recommended because of their simplicity. Properly designed and operated septic tanks will remove 50 to 60 per cent of the B.O.D. and suspended solids.

Where secondary treatment is necessary the recirculating biological filter is usually most satisfactory. The filter bed should provide 1 sq. ft. of surface for each 20 gal. per hour of capacity of the supplying pump. The filter should be operated continuously for maximum efficiency. It should consist of 6 ft. of hard granite rock screened to eliminate all except the size between 3 and 4 inches. Sketches covering the layout of equipment are included.

The chlorination process requires one or more tanks arranged in parallel and having a combined capacity of the maximum daily flow of the plant. Each tank is equipped with a stirring mechanism, chlorine diffuser and drain line.

After the wastes have been collected at the end of the day, the stirrer is started, and they are chlorinated for about one hour at a rate involving little surface loss of chlorine. The wastes are then mixed for an additional 15 min. after a 40 per cent solution of ferric chloride, in sufficient amount to equal a dosage of 1.5 lb. per 1,000 gal. of waste, has been added. After quiescent settlement overnight, the clear supernatant is separated from the sludge.

Chlorine is usually obtained in 150 lb. or one-ton cylinders. The stirring mechanism should be geared to a peripheral speed of about 60 ft. per minute. The disposal of sludge is the major problem in this process. If it can be discharged to a lagoon without odor nuisance, this is a good solution. If lagoons are not desirable, sludge can be hauled to land or a burying pit in an isolated location. If necessary, a heated sludge digestion tank having 25 to 30 days capacity can be provided.

Primary Treatment

Since waste treatment becomes more complicated as the size of the slaughtering plant increases, the remainder of the bulletin covers primary and secondary treatment in large plants. The processes considered applicable to slaughterhouse wastes and the efficiencies of each are shown in Table II.

TABLE II.—Removals Effected by Treatment Processes

Type of Treatment	Suspended Solids, %	B.O.D., %
Plain sedimentation	40 to 60	30 to 50
Chemical flocculation	50 to 70	50 to 70
Sedimentation and standard filter	70 to 80	80 to 85
Sedimentation and single stage filter	75 to 85	75 to 80
Sedimentation and two stage filter	85 to 95	80 to 90
Sedimentation and activated sludge	95 to 98	90 to 95

The following major processes and structures (for which sketches are shown) are parts of a treatment plant designed for plain sedimentation: (1) bar screen and/or comminutor to prevent large particles from getting into the system by straining them out or grinding them up, (2) grease interception—by approved interceptors or traps to keep grease out of the system and to permit recovery, (3) suspended solids removal—in rectangular or round tanks with sludge collecting mechanism, sometimes aided by use of a flocculent, (4) sludge digestion—at 80° to 95° F. in conventional sludge digestion tanks of designs particularly applicable to slaughterhouse wastes, and (5) sludge drying—on

underdrained sand beds supported on gravel or cinders.

In the chemical flocculation process a flash mixer, a flocculating tank, and the chemical solution and feed equipment are necessary. The ferric chloride, which must be kept in wood, rubber-lined, or protected concrete tanks, can be prepared by chlorinating copperas or iron. Advantage is taken in this process of the ability of chlorine to precipitate and flocculate blood proteins.

Secondary Processes

The secondary processes described must be preceded by primary sedimentation, grease removal, and sludge disposal.

In the standard filter installation with an approved application rate of 2 m.g.a.d., spray nozzles are not recommended because of clogging. Intermittent application of wastes is considered essential. Eighty cu. ft. of filtering media per pound of B.O.D. applied is considered desirable. A depth of stone of 6 ft. is considered most economical and a half-tile underdrainage system is satisfactory. A secondary settling tank with a detention period of about one hour for the maximum hourly flow is considered essential.

A high rate filter is similar in layout to the standard filter except that a diversion weir box and pumps for recirculation must be provided. In the recirculating type (for which sketches are shown), a filter depth of 4 ft. is satisfactory and 20 cu. ft. of media per lb. of B.O.D. should be provided. In a two-stage installation the first-stage filter should be similar to the recirculation type. The second should be of the same design except that the filter depth should be 6 ft. and it should provide 80 cu. ft. of stone per lb. of B.O.D. applied.

The activated sludge process has not been used to any great extent for the treatment of meat packing wastes, but it is felt that its use would be satisfactory if facilities are properly designed and operated. The wastes must be given primary treatment before the activated sludge process is used. The aeration tanks should be of sufficient capacity to hold the maximum daily volume of waste produced. Ample capacity for returning sludge should be provided. A secondary settling tank with a detention period of about three hours should be included.

KENNETH S. WATSON

Stream Pollution Abatement Standards Require Economic Justification. By R. B. WILEY AND W. E. HOWLAND. *Civil Engineering*, 17, 9 (September, 1947).

Pollution is defined as an unwarranted or unreasonable amount of objectionable substances contributed to the natural water of a stream which, because of the amount and kind, should be removed, counteracted, or prevented from entering the stream.

Orders for treament of wastes originating from public bodies must be issued in the light of reason. Such orders may be reviewed by the courts and their reasonableness would have to be sustained to be effective. There must be a balance between the cost of treatment and the benefits received.

Stream pollution abatement has many public health values. These are: (1) reduction to practical limits of the load on the water purification plants and the increased safety of the water so treated, and (2) the reduction in the danger of spread of disease by: (a) swimming and wading; (b) cattle wading in streams, the contamination of their udders, and the subsequent direct contamination of milk in the milking pail; (c) contamination of wells along stream banks; (d) contamination of legs and bodies of insects in floating and stranded filth and the subsequent contamination of food by the insects; (e) contamination of legs and bodies of water fowl swimming in polluted water and subsequent contamination of drinking water in storage reservoirs; and (f) contamination of fish, especially shellfish.

Situations where proposed sewage or waste treatment programs should not be undertaken without careful balancing of all advantages and disadvantages are: (1) where the public health is only remotely involved and where the money needed to build the project probably would be taken from funds needed for schools and school teachers; (2) where the quality of the stream water would be only slightly improved by the proposed project; and (3)

where the removal of the waste would result in the removal of an industry judged to be vital to the prosperity of the community.

Stream standards must be flexible and considered tentative. They are guides to judgment and should not become restraints to wise administration of water resources. The use of water will largely determine the required cleanliness. Standards may be prepared for a particular state on the basis of (1) general recreational uses of water, (2) use as a source of industrial water supply, and (3) use for the cultivation of fish.

RALPH FUHRMAN

Subsurface Disposal of Inland Oil-Field Brines. BY OGDEN S. JONES. *Civil Engineering*, 17, 2 (February, 1947).

Inland oil fields have a much more difficult problem of oil-field brine disposal than do seaboard oil fields where disposal in the ocean is ordinarily practiced. Oil-field brines ordinarily have salt contents of six times that found in sea water. The scarcity of fresh water in the inland oil fields makes disposal by dilution generally impossible and also requires that disposal techniques protect existing fresh-water sources.

The use of brine ponds has led to contamination of shallow ground water which is frequently an important source of water in the areas concerned. Any person leasing his land for oil-drilling purposes should insist upon proper brine disposal methods.

In several Kansas areas brine has been returned to subsurface formations approximately 4,500 ft. below the surface. One disposal well drilled to this depth may serve as many as 60 oil wells. Another method of disposal, the water flood, has been used successfully in Pennsylvania as well as in Kansas and Oklahoma. By this method, return of brines to the producing formation helps force out additional oil and, in addition, solves the disposal problem.

RALPH FUHRMAN

Three-Million-Dollar Tacoma Sewer Project Employs Machine-Made Joints. BY C. S. SEABROOK. *Civil Engineering*, 17, 6 (June, 1947).

Tacoma, Washington, is engaged in a three million dollar program of sewer improvements consisting of trunk sewers, a primary sewage treatment plant, and the extension of nine existing outfalls now discharging at high-tide line along the north shore of the city.

As the work has progressed, pipe bedding specifications have been revised so that all pipe will be on a first-class bedding material such as water-settled sand. A new-type joint was specified made up with cement applied with a Guniting machine instead of by conventional grouting methods. Especially tight joints resulted. It is believed that actual labor costs of the new joint will be much less than ordinary hand-mortared joints.

RALPH FUHRMAN

Stream Pollution Abatement Program Proposes Single Plant for 100 Municipalities. BY JOHN F. LABOON. *Civil Engineering*, 17, 3 (March, 1947).

Of the 127 communities in the area of Pittsburgh, Pennsylvania, 102 have been ordered to cease discharging sewage and industrial waste into the streams. Most of these communities are a part of the Allegheny County Sanitary Authority which will collect and treat the sewage of the area. Present standards for treatment are for 35 per cent removal of organic matter from the sewage.

To execute the program about 200 mi. of collecting and intercepting sewers will be required with a single treatment plant on the Ohio River below Pittsburgh.

The Authority has been measuring the sewage quantities and is now checking strength and quantity of wastes originating in more than 2,000 industrial plants of the county.

RALPH FUHRMAN